International Journal of Engineering Education Vol. 40, No. 1, pp. 154–165, 2024
Printed in Great Britain

0949-149X/91 $3.00+0.00

Learning to Cope in Undergraduate Chemical Engineering: A Comparative Study of Second Year Students Across Three Countries

NICOLE P. PITTERSON
Department of Engineering Education, Virginia Tech, 369 Goodwin Hall, 635 Prices Fork Road, Blacksburg, VA 24061, USA.
E-mail: npitters@vt.edu

JAN MCARTHUR
Department of Educational Research, Lancaster University, England. E-mail: j.mcarthur@lancaster.ac.uk

ASHISH AGRAWAL
Department of Chemical Engineering, University of Cape Town, South Africa. E-mail: atacet@rit.edu

ALAA ABDALLA
Department of Engineering Education, Virginia Tech, 369 Goodwin Hall, 635 Prices Fork Road, Blacksburg, VA 24061, USA.
E-mail: a.e.s.a.abdalla@tue.nl

JENNIFER M. CASE
Department of Engineering Education, Virginia Tech, 347 Goodwin Hall, Prices Fork Road, Blacksburg, VA 24061 USA.
E-mail: jencase@vt.edu
Department of Chemical Engineering, University of Cape Town, South Africa.

The impact of the time-pressured and demanding engineering curriculum has been shown in many studies to impact negatively on student success in engineering. To understand this phenomenon more closely, as well as to explore how different institutional and curricular contexts might offer different possibilities for students, this study draws on semi-structured interviews with 51 second year chemical engineering students at five institutions across three national contexts. The article reports findings on the interplay between the structures that both constrain and enable learning (especially via curriculum and assessment). We show that an important personal transformation for students across all contexts involves learning how to "cope" with the stringent structural requirements of their curricula. Additionally, we highlight how students across three national contexts describe their ability to cope or not with curriculum related demands. Our findings show that these demands vary by context in relation to how much scheduled class times students have, how students structure their weeks around pending deadlines and other assessments and as well as how students transition between coping and not coping based on the prior academic years' experience. Our study allows useful conclusions to be drawn about the influence of different curricular structures, and how best to support student engagement with demanding curricular and assessment structures. We show that learning to cope is not a passive process but involves active engagement of students with the curriculum. Further, we suggest implications for educators who are interested in supporting students successfully progress from one academic level to another.

Keywords: coping; workload; curriculum demands; chemical engineering students

1. Introduction

Over the last twenty years, researchers have sought to understand the complex and dynamic relationship between teaching and learning. Some of the key works have focused on the teaching and learning interactions that universities strive to foster [1], constructive alignment in curriculum design and content delivery [2] as well as the role of pedagogies in actively engaging students [3]. In the case of engineering teaching and learning, learning outcomes are highly dependent on the synergistic interaction between the curriculum, instructors, and students. The engineering curriculum governs the body of knowledge – what is taught, when it is taught – and the foundational concepts necessary for students to move from one level to the next. However, a key feature of the engineering curriculum is that it is tightly packed, high in content and requires from students a non-negotiable engagement with the foundations of disciplinary knowledge. When compared to students in the arts or social sciences, engineering undergraduates have less choice of subjects and less unstructured study time [4]. This article explores what this means for students' learning and challenges the idea that a highly structured curriculum necessarily means students passively follow a set path. Our findings reveal complex and thoughtful ways in which students learn to "cope" with the demands of

* Accepted 1 November 2023.

their degree programs as well as highlight the consequences for those students who struggle to do so.

Research has highlighted several core benefits that are achieved when students are actively engaged in the teaching and learning process. For example, several studies have found that students experience high levels of motivation and interest in the subject area when they make meaningful connections between what is being taught and what they already know [5–7]. While extensive work has been done on the role of motivation in engineering students' learning and engagement [8–10], few studies explore the impact of the time demand students experience as a result of the curriculum and demanding course workload. Consequently, students are often faced with the challenge of acquiring significant bodies of knowledge that are delivered in curricular formats that involve face to face time with lecturers, practical activities in the laboratory, usually some structured tutorial or project work with peers, and then "free" time in which students need to individually work through textbook-type problems, write up reports, and study for tests and exams. As these demands ramp up progressively from year-to-year students frequently must readjust what it means to cope. The consequences are severe for those who do not manage this transformation easily as can be seen in the failure and drop-out rates in engineering programs. In fact, research studies have attributed this high-rate of drop out between the first and second years to difficulties associated with making this transition to university, program and course related challenges as well as other personal reasons [11–13]. To this end, much work has been focused on higher education transition i.e. focusing on first years. Thus, it is important to also study how students are managing in the second year so as to better understand how students are making the transition to the next level of their degree.

In this article we report on our study with second year chemical engineering students in five different institutional contexts across three countries. The study found that an activity described as "coping" was the most common student experience of the complex demands of curriculum, workload, and time constraints. Analytically, we take coping to mean what occurs when an engineering student can clearly explain the course and assessment requirements and describe how they are able to meet these within the tight deadlines and busy curricular structures. In the study we also identified instances of students not coping as well as evidence of students in a transitional space between coping and not coping. Understanding these two exceptions to "coping" helps us to further understand this core phenomenon which, we believe, offers significant insights into how engineering students approach their curriculum and study practices. Across all five institutional contexts in the study we identified all three phenomena of "coping", "not coping", and "transition to coping", but the analysis probed further to understand where the curriculum better supports the transition to successful coping. Such insights can then inform how we as educators understand and support our students in terms of course design, content delivery and the amount and frequency of assessments.

2. Background

2.1 Theorizing Student Learning

Student learning is a complex social phenomenon, and thus we follow Ashwin's [1] position that there cannot be one theoretical lens that can fully capture all the significant aspects. Different lenses will produce different insights. Some lenses have been more prominent in the field, maybe because they match more closely our commonsense ways of thinking about learning and education. Much of this work understandably focuses its attention on the student and their individual acts of studying, the extent to which they acquire the knowledge that is the stated intention of the courses they are taking. Cognitive psychology has provided a rich set of conceptualizations that not only characterize the student's conceptual understanding (like approaches to learning) but also which aim to characterize students' motivations towards investing efforts in studying (motivation, self-efficacy, self-regulation, etc.) and their awareness of their learning strategies [5, 9, 14, 15].

There are other lenses that have aimed to better capture the broader social context of learning, the influence of others in the class environment that is a key feature of education even in traditional modes. There is much work that focuses on the linguistic aspects of learning, often tracing its origins to Vygotsky's work [16]. Further, there is a growing field that considers how students' sense of identity influences and is also an outcome of their learning [17, 18]. Many of these characteristics are still broadly with lenses that rest on a psychological theorization of the student and their learning. Following Ashwin [1], the value of this work should not be understated; it has offered significant insights into student learning, and particularly around how better learning outcomes might be fostered, through understanding to some extent the influence of the context in which learning takes place. This study is thus framed through a socio-cultural lens on engineering student learning, emphasizing the social context in which learning

takes place, and viewing learning as a complex interplay between the individual student and the structural and cultural context in which they find themselves [19, 20].

2.2 Research on the Transition to the Demands of University Studies

When students enter university, research indicates that they tend to encounter challenges of varying magnitude. Some of these challenges are associated with assimilating to university life, increase workloads and expectations, as well as other psychological and academic variables that impact the overall experience. However, "while university student success has been a national challenge, students enrolled in fields such as engineering as especially vulnerable to program noncompletion" [21, p. 512]. This risk of noncompletion and general feelings of being overwhelmed have been attributed to the high workload demands, high-stake assessments, as well as the overall rigidity of the engineering curriculum and students' experience of the same. To meet these demands, students have to develop ways and means of coping. For engineering students, prior literature highlights that coping has direct influence on students overall "academic success because the amount of effort students invest to reach a certain outcome is dependent on how they cope" [22, p. 201]. Further, research has shown that students tend to develop coping strategies, defined as "conscious volitional efforts to regulate emotion, cognition, behavior, physiology and the environment in response to stressful events or circumstances" [23, p. 89]. These strategies have been ascribed to students' individual beliefs about how capable they are of managing the multi-faceted demands imposed by their degree programs as well as how much control they perceive they have over the outcome.

2.3 Promoting Students' Well-being and Ability to Thrive in Engineering

Stress is a prevalent issue among engineering students and is often intensified by the demanding workloads and rigorous academic requirements they face [24, 25]. High levels of stress can have a detrimental impact on their ability to cope effectively. Chronic stress can lead to mental health issues such as anxiety and depression, hindering their focus, problem-solving skills, and overall academic performance [26, 27]. Additionally, stress can negatively affect physical health, causing sleep disturbances, fatigue, and weakened immune systems, further compounding the challenges of managing heavy workloads [26, 28]. In this context, stress management and well-being play a crucial role in engineering students' coping mechanisms. Students who prioritize self-care, engage in stress-reduction strategies, and maintain a positive mindset are better equipped to navigate the pressures of their programs [29]. By addressing stress and promoting well-being, educators can significantly enhance engineering students' capacity to cope with the demands of their coursework and, ultimately, their long-term success.

Moreover, the work of Jensen and colleagues centers on engineering students' well-being and their ability to cope with the challenges of their academic workloads [27, 29, 30]. These researchers highlight the importance of students being aware of the various strategies to mitigate stress and having the necessary support structures in place to alleviate the pressure caused by engineering stress culture. Well-being, encompassing both physical and mental health, plays a pivotal role in resilience and adaptability. Students who report a higher sense of well-being tend to exhibit greater levels of motivation, self-efficacy, and problem-solving skills, allowing them to tackle complex engineering projects and coursework with more confidence. Furthermore, well-being contributes to a more robust social support network, as students with better mental health are often more engaged in extracurricular activities and collaborative projects, which can help alleviate the pressure of demanding workloads. This underscores the significance of holistic support systems that promote well-being alongside academic excellence in engineering education.

While other studies of how students cope have explored the impact of coping on students perceived achievements, positive and negative motivation, stress and anxiety among other physiological responses, very little if any have explored what coping looks like among students in different national contexts in the same study. This work is built on the premise that the nature and demands of a degree program vary by context. In particular, different degree programs in different countries may have different course structure, class meeting times and outside of class demands associated with magnitude and frequency of homework, laboratory and or tutorial session. Thus, in this study, we investigate what it means for students to cope, why they may not be coping and how these curricular demands and workload expectation vary between three specific national contexts.

3. Study Design

3.1 Context for the Study

Data for this study were collected as part of a larger study that aimed at understanding undergraduate students' experiences of engaging with their disci-

plinary curricula in two disciplines (chemistry and chemical engineering) at six different universities in three different countries – England (with pseudonyms Erbium and Europium), South Africa (Samarium and Sodium), and the United States of America (Argon and Astatine). The larger study focused on two universities in each country to allow for institutional comparison within a country along with disciplinary and national comparisons in students' engagement with their studies. Data from one of the US institutions (Astatine) were not included in this study as only four chemical engineering students were interviewed in their second year. Below we provided a short description of each institution and brief characteristics of the chemical engineering program of each school. Pseudonyms for the institutions were created by the research team using chemical elements.

3.1.1 Description of Institutions

Argon – is a public land-grant research-intensive engineering focused institution in the USA. Land-grant institutions are mandated to provide educational opportunities whereby students can translate knowledge to practice, engaging in technological leadership and contribute to economic growth and global competitiveness with their respective states and nationally as well. At Argon, the chemical engineering program offers a combination of chemistry and engineering courses, for a Bachelor of Science degree. All first-year engineering students at Argon go through a general engineering program.

Erbium – is a research-led institution in England that also specializes in teaching. The institution aims to create and maintain a culturally diverse campus and to produce graduates that are highly employable. At Erbium, the chemical engineering program offers a three-year Bachelor's of Engineering Degree as well as a four-year Masters of Engineering Degree. These two programs share the same set of courses for the first three years. All first-year engineering students at Erbium go through a general engineering program.

Europium – is an institution with a strong teaching focus alongside its research activities in England that places emphasis providing students with high quality teaching and learning experiences. The institution seeks to prepare its graduates to take on professional roles in industry through work placements for all undergraduate students. At Europium, the chemical engineering program offers a three-year or four-year (inclusive of an optional one-year placement) Bachelor of Engineering Degree.

Samarium – is a research-intensive institution that is notably one of the most diverse in South Africa. Samarium aims to continue to support national growth through the production of graduates who qualifications and skills are internationally recognized and applicable in national and global contexts. At Samarium, the chemical engineering program offers a Bachelor's of Science (Engineering) and all first-year students go through a general engineering program, however students who are intending to major in Chemical Engineering take an introductory course for the major.

Sodium – is a South African research-intensive university with an aligned teaching and learning initiative aimed at promoting a national and international growth and development. Sodium aims to produce graduates desirous of eradicating poverty, promoting environmental awareness and making significant impacts on national health and democracy. At Sodium, the chemical engineering program offers a Bachelors of Engineering and all first-year students go through a general engineering program.

3.1.2 Contact Time

Table 1, previously published in [31] and [32], shows across each context the amount of time students are expected to participate in in-class sessions that may include lecture sessions, laboratories also referred to as practical in some contexts and other instructional activities such as recitations or tutorials which are sessions in which students meet in smaller groups with an instructor or teaching assistant to work through materials previously covered in the lecture sessions. The table demonstrates similarities and differences across each context per week in year two of the degree and is provided to contextualize further findings about how students describe their weekly course expectations later in this section.

Table 1. 2nd year contact time for five chemical engineering programs

University	Lecture hours per week	Practical hours per week	Tutorial hours per week	Total hours per week	Teaching weeks per academic year	Hours per academic year
Argon	15	2	2	19	30	570
Erbium	12	6	3	21	20	420
Europium	15	4	0	19	24	456
Samarium	20	6	5	31	24	744
Sodium	18	5	9	32	26	832

3.2 Data Generation

Data were collected in the form of yearly student interviews, video recording of lectures followed by instructor interviews, and course documents including student handbooks and course assignments. This article is based on the interviews conducted with second-year engineering students at the five institutions described earlier. Approximately 10 students in each of the participating universities were interviewed, making a total of 51 participants in the part of the larger study reported here. Each interview lasted for approximately 45–75 minutes and explored students' course experiences, assessment experiences, engagement with the discipline and disciplinary knowledge, their future plans, and wider university experiences including their living conditions and engagement in extracurricular activities. This article specifically focuses on students' course experiences that captured details about participants' lecture and self-study schedules and modes of learning both inside and outside the classroom. The institutional names and student names used are all pseudonyms and full ethical approval was received from the host institution and where necessary the participating institutions as well.

3.3 Data Analysis

The full interview transcripts were preliminarily coded by two members of the research team using the questions from the different sections of the interview protocol. Following preliminary coding of the full transcripts, one code focusing on "course experience" was selected for further analysis in this study. Our analysis started with a preliminary reading of the sections of the interview transcripts to get familiar with the data. Looking to identify codes that could capture prominent aspects of different student experiences, we created two codes: Not Coping and Coping. The Not Coping code captured students' discussion of their inability to achieve of intended results i.e., not meeting course demands or keeping on top of their studies outside of class time. The Coping code captured students' description of their ability to achieve the intended results while not expressing their own personal choices or strategies in doing so.

The next phase of analysis involved each author focusing on the second-year interviews from one project site with an analysis based on these two initial codes to students' coursework experiences. After assigning these codes to one set of second-year interviews each, the authors met and discussed the initial coding including any disagreements and clarifications in assigning the codes. This process led to refining the code definition and adding one more code into the coding scheme – Transition to Coping. The authors then recoded the interviews previously coded by them based on the modified coding scheme. Following this second round of coding, the authors discussed disagreements leading to further refinement of the definition for the three codes. Each author then reviewed the coding done by a different team member to achieve inter-coder agreement. Any disagreements in code definitions and coding of excerpts were then discussed among the team members.

4. Results and Findings

Across the data set, we found evidence of students' understanding of their experiences in terms of the above-mentioned codes. However, coping was the most prominent code across all the interviews. Looking closely at the phenomenon we came to understand coping not in deficit terms, but as a legitimate approach to simply focusing on students fulfilling the complex demands of their course. This is, we suggest, a legitimate end in and of itself given the demands of these degree programmes and the nature of knowledge being engaged with. Also, we found several instances where the same student would discuss not coping at one point while coping at another. This indicated that not coping and coping are not mutually exclusive categories but rather are experiences students have based on time and/or workload.

In this section we use illustrative quotes to highlight both the differences between these codes and what influences whether or not students are able to cope, not cope or when they describe making a transition from not coping to coping. Where appropriate we also highlight the comparative differences that have emerged between the national and institutional contexts.

4.1 What Does Coping Look Like?

Out of 51 interviews, 47 offered instances that we defined as "Coping", where students were able to describe the requirements of the course, and express the view that they are managing to deliver course deliverables on the tight schedules that are in place. Students often referred to assessed work at the point in the interview where they were asked "How are things going academically". Thus, keeping up with assessment demands was a common proxy for what we call coping, as demonstrated by this quote:

> "Fairly well. I've passed everything so far, so, I'm current with my course. I've managed to get a few distinctions here and there. We're getting our test week results back now and it's going well except for maths.

> Maths is a bit of a concern, but it's definitely salvageable" – Tiaan, Sodium University, South Africa.

It is important to note that the interview protocol did not explicitly ask students whether they were coping or not. The question was more broadly phrased as "How are things going?". Some students who were academically successful did not explicitly give expressions that we coded in this category. They might have indicated that second year was going well, or that they were working hard - but to be coded in this category we explicitly looked for a statement that said they were coping with delivering what the course needed:

> "Things are going pretty well actually. The pace has definitely picked up in terms of like course load and complexity of the material that we're learning but I think I've been able to keep up with it" –Arun, Argon University, US.

Thus, the distinction between coping and not coping is not in itself based on feeling stressed (even students who were "coping" frequently expressed feeling stress), but rather feeling it in such a way that inhibited completion of core curriculum requirements.

In the same way the students who are coping do recognize that the curriculum is placing enormous workload demands on them. But they are able to cope when they find ways to balance these competing demands:

> ". . . if I have a math test coming up, probably I'll make sure I finish all my tuts [tutorials] if possible, within the slot that they've been put in, and then when I go back home, I'll just focus on one. I feel like most time goes to Chem Eng because sometimes you don't finish the tuts in class, so you finish them at home. During project weeks it's like you only do one course, Chem Eng" – Nomathemba. Samarium University, South Africa.

In second year, it was evident that the multiple demands on students increase, and it was those students who can cope with this who stay on track:

> ". . . the work is getting more challenging, so one has to spend a bit more time with it. . .I'd also say there's more work because now we find ourselves writing more reports or more technical reports that have to be more professional also. Yes, and, for example, this past week I had two, even though, like, for the whole semester, that's still quite a lot more work compared to last year" – Tinotenda, Sodium University, South Africa.

In this study we were particularly interested in seeing how different institutional and curricular contexts influence students' experiences of coping. This is seen in the details of how students described what 'coping' requires, for example this quote from a South African student:

> "Every day I try to do the tut [tutorial], well, the next day's tut. The tuts are becoming bigger, it's not that a person, it's not like last year where a person could do almost the whole tut in the tut period. A person must work before. And for, yes. So it is, weekends are also very busy. And we have more tasks. First semester was very bad because every week we had a chemistry report and another four or five tuts for the week. Mondays we wrote almost two tut tests, so it was very rough. This semester is much much more relaxed actually. But it is more difficult. The subjects are extremely difficult" – Thomas, Sodium University, South Africa.

By contrast, the English and US students spoke of busy weeks, but they also had more free time in second year compared to first year, and their ability to cope depended on how they make use of free time. For example:

> "Last year, my timetable was full. It was about 16 hours a week. I have two hours lecture, one-hour break, one-hour tutorial, but this year when I have more time, I can organise my time much better. So, I keep focusing on each module better than last year" – Rasha, Europium University, England.

This quote from a US student indicated how much flexibility they have that they can allocate for their study time:

> "So, I kind of have free mornings and free afternoons on Monday, Wednesday, and Friday. I try to utilize those as much as I can. If there is a test that week, that's generally where I spend most of my time studying is during those days" – Alexander, Argon University, America.

Second year brought improvements in the ways these students coped with the intense demands the curriculum placed upon them. We saw students discussing how their experiences and increased familiarity with how their degree program work as key factors in coping:

> "Yes, I feel like I've changed a lot in terms of my skills. I've improved my time management skills. Last year I used to waste a lot of time, whereas this year, I'm forced to keep a track of time, look ahead. What kind of weeks do I have ahead of me? Do I have a relaxed week? What time do I start and finish and, possibly, if I can get some revision done in-between lectures? So, I'm constantly looking at where I can fit in revision and when I'll be going to work so I can plan ahead. So definitely my time management skills have improved a lot" – Raneem, Europium University, England.

Students also noted how the structure of assessment demands kept them focused on their work and, by second year, had helped them develop good working practices. For example, in the quote below, Lincoln discussed his experience of how the amount of assessment and the frequency with which they were assigned in the first year helped him in the second year to "cope":

> "I mean, the tutorials were once a week, you had to do 4 or 5 questions, maybe 2 or 3 sheets, so maybe 15 questions. I suppose they just kept you on your toes, stopped you from getting lazy, in a way. Even though we don't have them, I don't feel like I've gone lazy, do

you know what I mean? I feel like I'm staying on top more, if anything, because this year's more important, in terms of if you do it totally well this year and . . . You know, there's not really another chance'' – Lincoln, Erbium University, England.

4.2 Why are some Students not Coping?

The code ''Not Coping'' encompassed students' reports of struggling and/or failing to complete tasks associated with their day-to-day course expectations in a timely manner. This therefore goes beyond simply finding it stressful to cope, for example, to experiencing such stress they cannot function to meet course demands. Our analysis compared the experiences of students whose descriptions of their experiences were interpreted to be coping with those who were interpreted to be not coping. The key finding is not that these two groups are describing experiencing a different phenomenon, but that they described the same kind of experience differently. For example, as already noted, second year in the English institutions and the US sees a decrease in contact time (though it is still high compared with some other disciplines). Some of the students we heard from in the previous section suggested this gave them additional ''freedom'' to cope with the heavy workloads. Others, however, indicated that they missed the structure and found it harder to cope without it. At Erbium, for example, the tutorials which are such a feature of first year were not offered in second year. Some students said they struggled without the contact and structure they provide:

> ''I kind of like it because it gives us more time to just do our own thing, but I really liked the tutorials because it encouraged us to do the work. I feel that I'm the type of person that if I don't have a deadline then I probably just won't do it. Do you know what I mean? I'm not very good at motivating myself to do questions unless I've got a deadline to do. I will meet the deadline, but unless there's one there, I just don't do anything. It's been a bit of a challenge to try and change that. I probably would have preferred to have a few more tutorials this year'' – Luke, Erbium University, England.

Some reduction in contact time did not appear to mean, however, that the course workload diminished in any of our institutional or national contexts. Because engineering knowledge is hierarchically inter-related, a student who falls behind with the workload risks finding themselves completely unable to cope. Again, while those students who were coping found a strategy to deal with competing demands, these other students just could not keep up with all the demands on them. Thus, it appeared that if a deadline got missed in order to meet another deadline, and the whole problem of coping would begin to snowball:

> ''. . . that actual week were two of the busiest weeks since I've been in university. I had all my tests in those weeks. So, as you can assume, I didn't do very well in my tests, which is unfortunately because these classes, it's test dependent and that's it. If you do bad on a test, then you're not going to do well in the class, but it's really unfortunate. I guess that's just the way it is'' – Adrian, Argon University, USA.
>
> ''What happens during project weeks especially is that chemical engineering tends to forget about the other courses being there, that we have to work on our other courses. And sometimes we have practical hand-ins for chemical engineering itself during project week. And the time that that takes is not really considered, because we spend most of our. . . Every free minute we have, we spend working on those projects'' – Naas, Samarium University, South Africa.

The amount of work appeared to be a factor for all students who had trouble coping, in all our institutional sites. The South African students described the overwhelming load placed on them by their chemical engineering courses, specifically during what they refer to as project week in the discipline and how in trying to keep up with the chemical engineering course demand, which one student described as their ''main course'', they have often had to let other coursework slide. In the English institutions, the difficulty in coping as it related to course load/demand was often described as the sheer number of deliverables due in rapid succession for all their courses. Some students described the frequency as every week or every two weeks having assignments and exams for various classes. Students also discussed how trying to fit in time to revise and revisit the material as well as attending classes as the reason for them taking a break and thereby falling behind. For the US students, the impact of course loads often reflected the number of tests they had to do as well as the amount of preparation/studying which was further compounded by the fact that the difficulty level of the content is increased.

Closely linked to this heavy workload was the issue of having enough time to stay on top of things:

> ''It's a lot of things in a short period of time. That's, like, the measure. Some of the concepts I realize that I could've understood better, but because of time I just tend to rush over things'' – Nisha, Samarium University, South Africa.

Several students felt as though they would have a better handle of the topics being covered in class if they had the time to more deeply engage with the materials presented in their classes or participate in social activities. In the English and SA contexts, when students referred to not having enough time, it was usually attributed to being able to further explore or grasp course content while in the US the same theme was sometimes discussed in relation to

engaging in social activities with their friends, going to the gym or working part time jobs, all of which seem to be considered as central to their educational experience.

In the English institutions, there appeared to be a stronger tendency among students who were not coping to associate this with the approaches of their lecturers. A perceived lack of constructive feedback or a lack of willingness to answer questions seemed to be core problems these students encountered:

> "There were a couple of the questions where I made the same mistake. He [Instructor] just wrote that just as a general comment. You could see that I lost marks consistently because of the steps in the mechanism, but he didn't really suggest how I could improve. So, for this assignment, I struggled with the steps, and he's marked it and he's just going to leave it. So, he's not really helped me understand the steps further, if you know what I mean?" – Raneem, Europium University, England.

> "In terms of lectures, some lectures are good, and some are not so good. Some of them, there is just an hour of the lecturers talking and it's hard to learn that way. Some lectures are alright. When they have examples in the lectures, sometimes we're able to keep up with the examples and learn through that. Sometimes it's too much" – Laith, Erbium University, England.

Further, the students in the English institutions sometimes suggested that they felt overwhelmed by their lecture experiences. These included not having a lecturer who explains the material and answers their questions or, in some cases, not working through examples.

Finally, there was a sense that – probably for multiple and over-lapping reasons – these students who are not coping simply felt overwhelmed. Here are three illustrative quotes:

> "I had three labs for three modules back-to-back, which was just tiring" – Rachel, Europium University, England.

> "I'm just very tired. It's just too much, as I said in the beginning, it's too much to take" – Rachel, Europium University, England.

> "I thought I could handle it the first few months and then by the end I was kind of completely crashing. I don't have the best sleeping habits ever, so it definitely didn't help, I don't know. It felt like I was under a lot more stress" – Akio, Argon University, America.

The students' discussions that led to this sense of being overwhelmed varied, however, they collectively discussed being tired or stressed which often led to not being able to "stay on top" of things. For example, the South African students would discuss not being able to get any work done on the weekend or on days when they did not have classes because they pushed themselves so hard before, during and after classes all the time. On the other hand, the English students would discuss feeling like the amount of freedom they had in their labs added a new level of stress because they felt like they had no idea what was expected of them. While in the US institutions, the difficulty with coping was often attributed to not being able to balance all their responsibilities or making intentional choices to engage in non-academic activities that often impact their grades or ability to complete the work required of them.

4.3 Transition to Coping

It was equally important to explore how students may transition between these states of not coping and being able to cope. We highlighted this experience through the sub-code "Transitions to Coping" which referred to instances where students described previous experiences of not coping and contrasting these with the present where they are coping. We found 10 instances of students describing this transient state. Usually, they referred in these instances to having changed how they used their time, what they prioritized, and the strategies they employed. These themes are further explored below. What is important to note in this code was the emotional tone that tended to accompany it. While students were generally pleased with their ability to manage the demands of the course, especially if this was something they struggled to achieve, we often found they still described feeling 'stressed', as shown in these quotes:

> "Well, as I said, each week there's always something little for each thing. So normally after classes you have to spend time doing it for the next day. So sometimes it does feel like you're running on air, where you're just trying to meet each deadline but that's only on really busy weeks" – Tessa, Sodium University, South Africa.

> "I've got a bit more used to it and I feel like I am up to date with everything, I feel like I'm able to keep everything going. It is very difficult still and there's loads of trouble and trials, but it's still. . . I still feel secure enough to be continuing and stuff" – Naas, Samarium University, South Africa.

5. Discussion

We argue that our study contributes to the literature in the following ways (1) we characterize what it means for students to cope, (2) we provide an explanation of why students may not be coping specifically looking at how curricular demands and workload expectation vary between three specific national contexts and, by extension, institutional contexts. Our analysis identified three different categories: Not Coping, Coping, and Transition to Coping, across all national and institutional contexts. In the previous section we highlighted how these codes vary by context. Understanding the implications of these findings can be supported

by considering three broad areas supported by the literature – curriculum demands and contact time, time management skills or the lack thereof, and the overall influence of workload on engagement and learning. This work showcases the interplay between how students navigate the demands imposed by the structure of their respective context that in turn shape student actions inside and outside of the classroom. These findings are supported by studies of engineering stress culture and what it means for students to thrive in engineering. In particular, we highlight the importance of identifying the rigors imposed by the engineering curriculum in various institutional and national contexts and discuss potential coping strategies that students can be encouraged to pursue to ensure their successful transition from one academic year to the next.

5.1 Curriculum Demands and Contact Time

The influence of curriculum demands, and contact time was found to be common across all contexts. The most common experience of coping appears strongly shaped by the curriculum and the amount of contact time, and here we noted that both South African institutions required much more in-class time than the other institutions in this study, and this was evident in the experiences of students in these programs. Students who are coping are able to keep up with the demands of the curriculum, and in that sense, they study successfully. Some students, however, were unable to navigate multiple courses and their related classes and this leads to their being overwhelmed and thus not coping. In comparison, students who were coping were able to describe strategies that they have developed and are using to meet the demands of their courses.

The issue of curriculum demands on students' learning and overall university experience is well documented throughout the literature [33–35]. In fact, some studies have shown that engineering curricula and, by extension, engineering culture has a perception of meritocracy that defines success as being achieved through hard work, intelligence, and the disposition to navigate the challenges and rigor the discipline imposes [24, 28, 36]. The curriculum, individual course designs and assessment tend to address the need for high academic standards and the ability to apply complex problem-solving skills where students must demonstrate from one level to the next academic excellence and exceptional problem-solving skills. Our findings suggest that many engineering students can successfully cope with these demands, understood purely in academic terms, which then comes at the expense of students' mental health, stress levels and can lead to being burned out. Consequently, several studies have advocated for the design of curriculum that affords students the opportunity to maintain some sense of balance between their academic and social life [37–39]. Universities should prioritize mental health support services and resources that are specifically tailored to engineering students that provide them with stress management strategies, mentorships and tutoring where needed, as well as encouraging a growth mindset [40]. It is less clear that all our coping students achieved this balance, especially in the South African programs where students spoke about non-academic activities to a much lesser extent than others, most especially the American students, who spoke readily about maintaining this balance. These findings suggest that programs in contexts like South Africa could be productively looking to the US for exemplars on curriculum reform.

5.2 Time Management Skills

The influence of time management challenges was present across all contexts and in the three main codes that guided the analysis. Time management is essential for engineering students facing heavy workloads. With good time management skills students are able to prioritize tasks, set specific goals, and create well-structured schedules to ensure they are meeting deadlines and completing assessments in a timely manner [25]. Central to the experience of coping was often students' claims that they can "manage their time well". For these students this meant in a sense of having their studies, homework, and meeting deadlines under control. As mentioned in the previous section, these students often report having a system they are applying to their daily and weekly schedules to ensure all their course related work is completed on time. Students spoke readily about the impact of course structures, and tasks like tutorials and homework assignments.

The students at one English institution who had experienced a dramatic decrease in this kind of structured support with the move to second year found this challenging. Students who were not coping attribute this to the struggles they experience in attempting to do so with not having enough time. With a less regimented time demand, the English and American students described being able to make informed decisions about how much time they dedicate to their studies, what work/study tasks they engage in at any given time as well as other co-curricular activities. These findings are supported by research that posit effective time management is associated with greater academic performance [41, 42] in students. As Krause and Coates [43] purport "the capacity to successfully manage their time is the foundation of students developing good study habits and strategies for

success'' [p. 496]. Since good time management often leads to students having better control over their academic and co-curricular activities, it is important that students develop these skills.

5.3 Overall Influence of Workload on Engagement, Learning and Developing Agency

Our research painted a detailed and up to date picture of what it means to study in the engineering. These degree programs are considered vital to social and economic progress and also likely to offer significant benefits to the individual. As mentioned before, students are often faced with the challenge of acquiring significant bodies of knowledge delivered in multiple curricular formats such as face to face time with lecturers, lab activities and other less structured work [34, 44]. Our findings align with previous literature that discusses the impact of heavy workload on students' ability to successfully complete the various course related tasks, manage their stress levels and maintain a positive state of well-being. According to [4] and [37], increasing high workloads and time pressures often result in students feeling overwhelmed by tight deadlines and thus having to work long hours. This leaves very little room for students to fully engage with the content in a conceptual way sometimes which can greatly impact their ability to learn content in a deep manner [14]. Also, the demanding nature of academic assignments, projects, and exams, particularly in engineering and other STEM fields, can create a sense of pressure and urgency. Consequently, students may find themselves faced with a heavy workload that requires intense concentration and effort, leaving them with limited time for other activities or personal relaxation [36], [40]. The combination of tight deadlines and high workloads can lead to time scarcity, where students are compelled to work extended hours, often into the late hours of the night as can be seen from the discussions of the students in our study. This not only affects their physical health by disrupting sleep patterns but can also contribute to stress and mental exhaustion.

Our study also found that across the national and institutional contexts, many students do affect this transformation even from the first year. As the demands ramp up progressively from year-to-year students must readjust what it means to cope. Though the consequences are severe for those who do not manage this transformation easily, in this work, we note students who, by taking more flexible routes through the curriculum, are managing to make this change. A particular interest for this study was to also identify where students are actually moving beyond coping and into exercising agency as engineering students and future professionals. While we noted limited evidence of this from the second year, future research will explore how students are developing agency into their third year of study.

6. Limitations and Opportunities for Future Work

This work is not without its own set of limitations. Firstly, we did not code any instances of students going from coping to not coping. We acknowledge this may be a function of the way in which our codebook and analysis plan was developed. Further analysis could be done of our existing data set to examine each students' individual trajectory to see if there were any occurrences of this phenomenon.

Secondly, due to low numbers for the second US institution (Astatine) we opted to not include the four interviews in the analysis. Another study could have been conducted with first and second-year chemical engineering students at an institution of similar features to our missing institution to increase the number of US students in our dataset. Further, we interviewed the same students at both US institutions, and saw an increase in students' response from Astatine in the third and fourth years thus it is possible to replicate this study with students across all six institutions.

7. Conclusion

This study offered insights on certain aspects at the core of higher education which point to its enduring power – in that it affects substantial transformation on young people over a limited number of years through structural mechanisms that are both constraining and enabling. We have highlighted that students, once in university, find themselves subject to significant demands that they have to learn how to figure out. This process of learning to cope is an essential part of their formation as engineering students.

This work has highlighted that in order for engineering students to successfully progress from one academic year to the next it is imperative that they are coping and applying specific coping strategies on their own. Coping strategies such as good time management skills, study skills, stress management and other relaxation techniques such as meditation, or physical activities known to reduce stress should be recommended to students by their instructors and or advisors as necessary activities to pursue. Other academic activities that can help students to stay on track such as tutoring, help seeking, using digital resources to manage assignment due dates and other associated deadlines are useful coping strategies students should be made aware of. Our findings show that there is in fact a relatively small threshold

between coping and not coping in that course loads and competing time demands leave very little room for students to take a break. Comparing different institutional contexts, we show the impact of different program structures. The South African programs had a high demand on in-class time which impacted strongly on students' coping. In something of a contrast, the English programs had considerable free time but also much less structure in the course demands, which students also found challenging. The US programs seems characterized by considerable free time but also much ongoing academic scaffolding in class. These findings would seem to suggest that a decrease in contact time could be desirable, to allow students to manage their out-of-class time, but at the same time that the move to less structure in the course requirements should be managed gradually from year to year. This would provide students with the opportunity to engage in the various coping strategies that they can further build upon as they progress to achieving their degrees.

Overall this work highlights the importance of effective time management, efficient study habits as well as being able to adapt to changing demands as necessary skills in helping students navigate pursuing an engineering degree. Additionally, it underscores the significance of self-care, stress management, and maintaining a positive mindset to enhance overall well-being. As the demands of undergraduate engineering education continue to evolve, understanding how students are learning to manage curricular demands while developing coping strategies becomes increasingly crucial in ensuring the success and health of students.

Acknowledgements – This article is from the Centre for Global Higher Education (CGHE) Understanding Knowledge, Curriculum and Student Agency Project. We acknowledge the contribution of project team members: Paul Ashwin, Margaret Blackie, Reneé Smit, Janja Komljenovic, Kayleigh Rosewell, and Benjamin Goldschneider.

Funding Details – The support of the Economic and Social Research Council and Research England (grant references: ES/M010082/1, ES/M010082/2 and ES/T014768/1) and National Research Foundation, South Africa (grant reference: 105856) is gratefully acknowledged as well as the support from CGHE. The data reported in this article will be deposited with the UK Data Service once the research is complete.

References

1. P. Ashwin, Conceptualising teaching and learning interactions in researching higher education, in *The Routledge International Handbook of Higher Education*, Routledge, pp. 37–46, 2009.
2. J. Biggs, Enhancing teaching through constructive alignment, *High. Educ.*, **32**, pp. 347–364, 1996.
3. K. A. Smith, S. D. Sheppard, D. W. Johnson and R. T. Johnson, Pedagogies of engagement: Classroom-based practices, *J. Eng. Educ.*, **94**(1), pp. 87–101, 2005.
4. K.-A. Thornby, G. A. Brazeau and A. M. H. Chen, Reducing student workload through curricular efficiency, *Am. J. Pharm. Educ.*, 2023.
5. J. S. Eccles and A. Wigfield, Motivational beliefs, values and goals, *Annu. Rev. Psychol.*, **53**, pp. 109–132, 2002.
6. I. Stupans, S. Scutter and K. Pearce, Facilitating Student Learning: Engagement in Novel Learning Opportunities, *Innov. High. Educ.*, **35**(5), pp. 359–366, 2010.
7. H. Bajwa and P. Mulcahy-Ernt, Redesigning teaching approaches for undergraduate engineering classrooms, pp. 1–4, 2012, doi: 10.1109/ISECon.2012.6238558.
8. J. R. Morelock, A systematic literature review of engineering identity: definitions, factors, and interventions affecting development, and means of measurement, *Eur. J. Eng. Educ.*, **42**(6), pp. 1240–1262, 2017.
9. H. M. Matusovich, R. A. Streveler and R. L. Miller, Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values, *J. Eng. Educ.*, **99**(4), pp. 289–303, 2010.
10. P. R. Brown, R. E. Mccord, H. M. Matusovich and R. L. Kajfez, The use of motivation theory in engineering education research: A systematic review of literature, *Eur. J. Eng. Educ.*, **40**(2), pp. 186–205, 2015.
11. R. M. Marra, K. A. Rodgers, D. Shen and B. Bogue, Leaving engineering: A multi-year single institution study, *J. Eng. Educ.*, **101**(1), pp. 6–27, 2012.
12. J. R. Casanova, R. Vasconcelos, A. B. Bernardo and L. S. Almeida, University dropout in engineering: motives and student trajectories, *Psicothema*, **33**, pp. 595–601, 2021.
13. S. Pal, Mining educational data to reduce dropout rates of engineering students, *Int. J. Inf. Eng. Electron. Bus.*, **4**(2), p. 1, 2012.
14. B. A. Greene and R. B. Miller, Influences on achievement: Goals, perceived ability, and cognitive engagement, *Contemp. Educ. Psychol.*, **21**, pp. 181–192, 1996.
15. A. H. Schoenfeld, Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics, in *Handbook for Research on Mathematics Teaching and Learning*, D. Grouws, Ed. New York: Macmillan, 1992, pp. 334–370.
16. W. C. Newstetter and M. Svinicki, Learning theories for engineering education practice, in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Eds. New York: Cambridge University Press, pp. 29–46, 2014.
17. J. P. Gee, Identity as an analytic lens for research in education, *Rev. Res. Educ.*, **25**, pp. 99–125, 2001.
18. I. H. Settles, When multiple identities interfere: The role of identity centrality, *Personal. Soc. Psychol. Bull.*, **30**(4), pp. 487–500, 2004.
19. J. A. Siddiqui, C. Allendoerfer, R. S. Adams and B. Williams, Integration of scholarship: Interconnections among three studies on becoming an engineering education researcher, *Int. J. Eng. Educ.*, **32**(6), pp. 2352–2377, 2016.
20. A. Johri and B. M. Olds, Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences, *J. Eng. Educ.*, **100**(1), pp. 151–185, 2011.
21. A. S. Negi, A. Khanna and R. Aggarwal, Psychological health, stressors and coping mechanism of engineering students, *Int. J. Adolesc. Youth*, **24**(4), pp. 511–520, 2019.
22. P.-H. Hsieh, J. R. Sullivan, D. A. Sass and N. S. Guerra, Undergraduate engineering students' beliefs, coping strategies, and academic performance: An evaluation of theoretical models, *J. Exp. Educ.*, **80**(2), pp. 196–218, 2012.

23. B. E. Compas, J. K. Connor-Smith, H. Saltzman, A. H. Thomsen and M. E. Wadsworth, Coping with stress during childhood and adolescence: problems, progress, and potential in theory and research, *Psychol. Bull.*, **127**(1), p. 87, 2001.
24. K. J. Jensen, J. F. Mirabelli, A. J. Kunze, T. E. Romanchek and K. J. Cross, Undergraduate student perceptions of stress and mental health in engineering culture, *Int. J. STEM Educ.*, **10**(1), p. 30, 2023.
25. N. Ban, H. Shannon, C. J. Wright, M. E. Miller, L. E. Hargis, E. L. Usher, J. H. Hammer and S. A.Wilson, Identifying common perceived stressors and stress relief strategies among undergraduate engineering students. Paper presented at the *ASEE Annual Conference and Exposition*, Minneapolis, MN, 2022.
26. R. Kausar, Perceived Stress, Academic Workloads and Use of Coping Strategies by University Students, *J. Behav. Sci.*, **20**(1), 2010.
27. K. Beddoes and A. Danowitz, In their own words: How aspects of engineering education undermine students' mental health. Paper presented at the *ASEE Annual Conference and Exposition*, Minneapolis, MN, 2022.
28. K. J. Jensen, S. R. Vohra, J. F. Mirabelli, A. J. Kunze, I. Miller, T. E. Romanchek, CAREER: Supporting Undergraduate Mental Health by Building a Culture of Wellness in Engineering. In *Proceedings of the ASEE Annual Conference and Exposition, Virtual,* 26–29 July 2021.
29. S. J. Bork and J. Mondisa, Engineering graduate students' mental health: A scoping literature review, *J. Eng. Educ.*, **111**(3), pp. 665–702, 2022.
30. J. S. Gesun, J. C. Major, E. Berger, A. Godwin, K. J. Jensen, J. Chen and J. M. Froiland, A Scoping Literature Review of Engineering Thriving to Redefine Student Success, *Studies in Engineering*, **2**(2), p. 19–41, 2021.
31. N. Pitterson, J. Case, A. Agrawal and K. Krost, National, disciplinary and institutional influences on curriculum: A preliminary exploration across two Washington accord countries, Paper presented at the *Higher Education Close UP Conference 2019*, Cape Town, SA.
32. N. Pitterson, J. Case, A. Agrawal and I. Hasbun, Investigating the ways in which student agency develops through engagement with knowledge, in *Proceedings – Frontiers in Education Conference, FIE*, 2019, vol. 2018-Octob, doi: 10.1109/FIE.2018.8658556.
33. P. Ramsden and N. J. Entwistle, Effects of academic departments on students' approaches to studying, *Br. J. Educ. Psychol.*, **51**(3), pp. 368–383, 1981.
34. J. A. Centra, Will teachers receive higher student evaluations by giving higher grades and less course work?, *Res. High. Educ.*, **44**(5), pp. 495–518, 2003.
35. D.Gerrard, K. Newfield, N. Asli and C. Variawa, Are Students Overworked? Understanding the Workload Expectations and Realities of First-Year Engineering. 10.18260/1-2-27612, 2017.
36. D. Chadha et al., Are the kids alright? Exploring students' experiences of support mechanisms to enhance wellbeing on an engineering programme in the UK, *Eur. J. Eng. Educ.*, **46**(5), pp. 662–677, 2021.
37. E. Kyndt, I. Berghmans, F. Dochy and L. Bulckens, 'Time is not enough.' Workload in higher education: a student perspective, *High. Educ. Res. Dev.*, **33**(4), pp. 684–698, 2014.
38. A. L. Welker and B. Wadzuk, How students spend their time, *J. Prof. issues Eng. Educ. Pract.*, **138**(3), pp. 198–206, 2012.
39. E. Chambers, Work-load and the quality of student learning, *Stud. High. Educ.*, **17**(2), pp. 141–153, 1992.
40. N. Korsten, K. Wolff and M. J. Booysen, Time for mentally healthy engineering students, in *2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC)*, pp. 101–109, 2021.
41. J. P. Martin, A. C. Emberley, K. Douglas and R. Soto-perez, Engineering Students' Social Networks and Alters During the COVID-19 Pandemic, *Int. J. Eng. Educ.*, **38**(5), pp. 1643–1659, 2022.
42. R. V Adams and E. Blair, Impact of time management behaviors on undergraduate engineering students' performance, *Sage Open*, **9**(1), p. 2158244018824506, 2019.
43. K. Krause and H. Coates, Students' engagement in first-year university, *Assess. Eval. High. Educ.*, **33**(5), pp. 493–505, 2008.
44. National Research Council, *Identifying and supporting productive STEM programs in out-of-school settings*. Washington D.C.: The National Academies Press, 2015.

Nicole P. Pitterson is an Assistant Professor in the Department of Engineering Education at Virginia Tech. Her research interests are fostering conceptual understanding through the design of engineering learning environments and the assessment of student learning.

Jan McArthur is a Senior Lecturer in the Department of Educational Research at Lancaster University. Her research interests span two themes: education and social justice, and the nature of higher education. Her recent work has looked at the nature of assessment and feedback the role of failure in learning including the relationship between conceptions of failure and social justice.

Ashish Agrawal is an Assistant Professor in the College of Engineering Technology at Rochester Institute of Technology. His research interests include exploring the influence of curricular and pedagogical features on STEM students' academic experiences and creating equitable pedagogical interventions and studying their implementation. Ashish has also taught several introductory engineering courses using student-centric approaches such as problem-based learning and flipped classroom.

Alaa Abdalla is a PhD Candidate in the Department of Engineering Education. Her research interest is exploring the reasons students attend university and the overall global expectations of why students pursue higher education.

Jennifer M. Case is a professor and head of the Department of Engineering Education at Virginia Tech. She is also an honorary professor in the Department of Chemical Engineering at the University of Cape Town, SA. Her research seeks to answer how can teaching in engineering be improved to support student learning? What engineering curricula are best suited to producing the kinds of engineering graduates that society needs? What can we learn from engineering education systems in other parts of the world?