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A comparative study of curricular differences and their influence on students' formation as engineers

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Abstract

Engineering curricula, even within the same discipline, can vary widely. International agreements like the Washington Accord and most national accreditation frameworks seek to ensure some equivalency between engineering programs, but there is considerable scope for differences in curriculum structure and content. These differences may have considerable influence on students' experience through their degrees in terms of study patterns, academic success, transition from high school to the university, and progress through the degree. To understand the influence of curricular arrangements on student experiences, this article seeks to study and compare the undergraduate engineering curricula at four different engineering institutions in two Washington Accord countries – South Africa and the United States.

Data were collected from the four participating engineering programs in the form of curricular documents and student interviews. Data were analyzed to understand how the curriculum relates to local and national contexts and responds to the social and economic situations in a country. Additionally, we were interested in exploring how the curricular requirements including contact hours and other course requirements influence students' formation as engineers.

Preliminary findings suggest that there exist differences not only across national boundaries but also institutional lines in the course structures, credit requirements, and contact hours. These differences determine how soon students start forming an affinity to their discipline and how much they can explore other academic and extra-curricular interests. We expect that the findings will highlight the potential impact of different curricular features on the students who experience them, and provide engineering educators and program coordinators with informed choices to design curricula to better address their needs.

1. Introduction

Engineering education is an important area for debate in many countries, given the important roles that engineers play in national economic competitiveness, security and social advancement [1], [2]. Central issues in this debate include the attractiveness of the career for prospective students, the retention of those students who enter the program, the diversity of students in the program, and then the degree of fit between program outcomes and the needs of the workplace. Within this debate it is generally assumed that the curriculum is the arena in potential need of reform [3]–[5]. Curriculum reform deliberations tend to operate at a relatively high level, with a central tension between "theory" (engineering and basic science content) and "practice" (professional skills, often in project type context) [6].

A relatively recent focus for global curriculum discussions has been the spread of outcomes-based criteria for accreditation through the mechanism of the Washington Accord. From the early 2000s onwards, this has involved programs across a wide range of countries (excluding non-UK Europe and Latin America, but otherwise involving nearly all other major players in the field) accrediting their programs on an outcomes basis [7], [8]. For most programs, this has involved a change toward more explicit inclusion of "practice" type aspects in the curriculum, and assessment of these.

Although there has been intensified homogenization of these aspects of the engineering curriculum, the impact has been generally at a high level, especially involving capstone-level assessments. Accreditation has always also involved some degree of overall content analysis, for example, in the hours spent on particular subject areas, for example, mathematics, but this also tends to be at a reasonably superficial summary level [9], [10]. What has received considerably less focus is a comparison of the actual details of particular curricula. This high-level focus has been an important aspect of enabling global systems of accreditation and, we would argue, important in terms of institutional and national autonomy. But it has also meant there is very little global comparison of substantial differences in the actual details of how engineering curricula operate in different parts of the world.

Some scholars have outlined the distinctive different national cultures influencing the evolution of engineering programs in these countries. For example, Downey et al. suggest that a defining feature of UK engineering education is using practical knowledge in solving engineering problems, while use of first principles is emphasized in France, and attention is given to precision in Germany [11]. Many scholars (e.g., see [12]) have tracked the shift toward more advanced engineering science in US curricula following the spectacular technological developments during World War II, the influence of European scientists and engineers in the post-War period, and intensified concerns during the Cold War.

The overall project is tracking students through all years of their degree to graduation, but the present paper only works with data from the first two years of student interviews. This is crucial work for developing the analytical approaches that allow for comparison across programs. It is also significant to identify aspects of the structuring of the early years of the program that seem particularly influential on how they form prospective engineers. At this stage though it is not possible to draw conclusions about overall program-level outcomes or the employment trajectories of graduates.

In this paper, we explore the curricular differences in terms of structuring of the degree, curricular choices and contact hours, and how differences in these aspects influence the formation of engineering graduates. We focus on two countries that have their engineering programs accredited through the Washington Accord - South Africa and the United States. In each country we have selected two institutions, and within these we focus on a particular engineering degree (chemical engineering) in order to facilitate comparison.

2. Theoretical Framework

In this study, our focus on comparing curricula is not an end in itself, but returns to the curriculum debate which recognizes that the curriculum plays a key role in determining the kind of engineering graduates that a system produces. This focus means that a theoretical position is needed to inform how such an investigation might proceed. If it is assumed that students are empty vessels that have knowledge poured into them, then a simple comparison of topics and assessments would suffice to inform the analysis. However, this project does not view student learning in such a way, but rather views the active engagement of the student with knowledge as a key influence on their formation [13].

To accomplish such an exploration, a sociological perspective is thus of value. Here we look to analytically distinguish the features of both structure and agency, in order to understand the interplay between these. We draw on the work of sociologist Margaret Archer [14], with her work as recontextualized for application in researching student learning [15]. In the context of this investigation, the main structural feature that students encounter in engineering education is the curriculum. The curriculum offers both significant affordances and constraints for engineering students and it is important to describe and compare these across different contexts. In terms of conceptualizing the agency part of this interplay, we look at how students use their time and the choices that they make. We are also interested to see how the curriculum influences students to talk in particular ways about their studies.

3. Data Collection & Analysis

Data for this study were collected as part of a larger longitudinal study exploring the influence of disciplinary curricula in the development of disciplinary identity and student agency in two different STEM disciplines – chemistry and chemical engineering [16], [17]. For the larger study, data are being collected at six universities in various forms, including course documents, student interviews, lecture recordings, and lecturer interviews, in three different countries. For this paper, we analyzed the curricular documents collected from chemical engineering programs at four of the six institutions under study – two in South Africa and two in the US – and student interviews conducted in the first two years of the study in each program. The two South African universities are referred to as *City* and *Town*; and the two US universities are called *Residential* and *Commuter*. All four institutions are publicly funded research-intensive institutions, offering accredited four-year engineering qualifications in multiple disciplines. Table 1 provides some details about the institutions.

Table 1: Overview of institutions in this study

University pseudonym	**Town**	**City**	**Residential**	**Commuter**
Location	S. Africa	S. Africa	USA	USA
Source of funding	Public	Public	Public	Public
Campus type	College town	Suburban	College town	Suburban
Other details	Historically Afrikaans research university	Historically English research university	Land-grant research university	Space-grant research university

Curricular documents collected for the study include faculty and institutional publications documenting course schedules and credit requirements. Student interviews explore a range of topics including those related to course learning, assessment, relation to discipline, plans after finishing their degrees, and extra-curricular engagements. For the study, we are tracking about ten students in each of the two programs at the participating institutions by interviewing them once in the second half of the academic year. Students being interviewed for the study represent variation in race, gender, and nationality.

Data were analyzed in two steps. The first step involved analysis of the curricular structure. Using the chemical engineering curriculum documentation from each institution, we analyzed the curricular documents to contrast the curricular choices afforded to students at different institutions. We identified features of the curriculum structures that 1) are evident in the available documentation, and 2) potentially relate to the experiences of the students interviewed.

The second step of data analysis involved identifying excerpts from student interviews conducted in the first two years to provide evidence for the influence of different curricular features on students' experiences. We specifically looked for instances that explore students' perceptions of how they relate to their courses and their discipline, and how they spend their time when the university is in session. It should be noted that for this paper, we focused on identifying exemplars of quotes related to the influence of curricular structure on students' experiences rather than establishing a sense of prevalence across all interviewees.

4. Results

Based on our analysis of the curricular documents, we found three major areas of curricular differences at the institutions under study: first year of study, curricular choice, and contact time. The following sections discuss these areas in detail. The discussion of each of them is followed by an exploration of how a particular curricular structure influences students' experiences. Exemplar quotes from student interviews are used to highlight the curricular influences. It should be noted that pseudonyms are used for students to protect their identity.

4.1 First year of study

One of the biggest differences in the chemical engineering curricula at the four universities is in terms of how the first year of study is structured. There are two significant aspects of structuring of the first year: 1) process for admission of students into the major, and 2) exposure of students to program-specific content. Here we define program-specific content as courses that are taken primarily by the chemical engineering students and are not common for students across several engineering disciplines. The program-specific courses may or may not include chemical engineering courses. Table 2 summarizes how the first year at the four universities is structured.

With respect to admission of students into the chemical engineering major, students at three out of four universities (City, Town, and Commuter) are admitted into chemical engineering at the start of the first year. On the other hand, first-year engineering students at Residential University are admitted into the general engineering program at the start of the first year. They can only choose a major at the end of their first year based on their interest and academic performance in the first year.

With respect to exposure of students to program-specific content, only one of the four institutions under study, City University, introduces significant amount of content related to chemical engineering in the curricula starting the first semester of the degree. As evident in Table 2, program-specific courses account for about two-thirds of the credit requirements in the first year at this university. Moreover, of all courses taken by students in the first year, chemical engineering courses account for about 30% of the credit requirements.

On the other hand, at the other three institutions under study (Town, Residential, Commuter), all or most of the first year of the engineering program is the common for new engineering students across multiple disciplines. As shown in Table 2, students at these three universities take only about 0-12% courses that are specific to chemical engineering curriculum. This approach allows students to select or change their engineering field after gaining experience and knowledge about the various disciplines. Common first-year subjects include interdisciplinary introductions to engineering, introductory mathematics and science, and other classes satisfying generic degree requirements.

At Town University, program-specific coursework is present in the form of one chemistry course out of different first-year courses that students are required to take if they want to pursue chemical engineering in subsequent years. Commuter University has a similar approach - common first-year subjects across multiple disciplines with a minor variation for chemical engineering students specializing in biotechnology. As shown in Table 2, students who want to specialize in biotechnology are required to take one biology course in the first year, while those who do not specialize in biotechnology take all common first-year courses. It should again be noted that even though student get exposed to a little content specific to chemical engineering, they are enrolled in the chemical engineering program.

While students at Residential University are admitted to a general engineering program, it is recommended that students who plan to pursue chemical engineering take more chemistry courses than required for other disciplines. However, the university does not prevent students to pursue chemical engineering starting the second year of the degree if these additional chemistry courses were not completed in the first year.

Table 2: Breakdown of first-year subjects in chemical engineering programs

	Town	**City**	**Residential**	**Commuter**
Admission program	Chemical Engineering	Chemical Engineering	General Engineering	Chemical Engineering
% credit requirements program-specific	4.0%	63.0%	12.1%	0% (8.8%)
% credit requirements common	96.0%	37.0%	87.9%	100% (91.2%)
Program-specific first-year subjects	Chemistry	Chemical Engineering, Chemistry, Statistics	Chemistry	-- (Biology)

Note: Commuter University has different first-year requirements for students specializing in biotechnology, indicated in parentheses.

These curricular differences manifested in how students related to their discipline in the first-year interviews. At City University, we found evidence that some students showed an affinity toward chemical engineering right in their first year. For example, one student noted:

> *In our chemical engineering course… we have guest speakers who come back and tell us what they do and what opportunities are out there and what their careers were like; so we learn from that. We are also doing this assignment… to find a chemical engineer and correspond with them through email about what their job is like. [Through these activities] you get a better idea of what is expected of us [when we graduate]. [Nisha, Year 1, City University]*

In this quote, Nisha talks about how through the guest speakers in her chemical engineering course, she is learning about the job opportunities she will have after finishing the degree. These connections help her start developing an affinity toward her degree and the chemical engineering profession.

On the other hand, students at Town, Residential, and Commuter at times struggled to see the relevance of their first-year courses toward their chemical engineering degrees. The following quotes exemplify this phenomenon:

I didn’t think the first year would be as general as it is because as much as I registered for Chemical Engineering, right now the majority of my modules have nothing to do with Chemical Engineering, so that was something I didn’t expect and that was a bit stressful sometimes because you are having to study what you don’t like. [Tammy, Year 1, Town University]

I feel like the whole idea like the general engineering program, like I understand that university wants students to go into their major with the certain knowledge base but I don't think the general engineering course has been particularly helpful because whatever skills you focus on - there's very limited coding or it's sketching, which is very narrow in terms of which [kind of] engineers actually use [it]. [Sameer, Year 1, Residential University]

I don't think my Intro to Engineering class was a very useful class. I don't think it really taught me anything. I think that class could be more specialized towards each of the different engineering disciplines. [Marley, Year 1, Commuter University]

It should be noted that while students could not see the relevance of the courses they took in the first year, several students commented on how the courses they were doing in the first year started to feel more relevant in the second year once they started to take courses specific to their major as the following quotes suggest:

First year it was more general, and first year I used to question “do we really need this? Not”. But now I can actually understand like, “okay, I did this module in first year because it was going to help me understand this and that, and this and that”. And now it’s more towards what exactly I wanted to do initially. [Tawanda, Year 2, Town University]

Last year it was more of an overview of all the things you can maybe eventually learn or you could do. And this year, now that I've declared [my major], I'm learning the nitty gritty details of it. [Emily, Year 2, Residential University]

I think the main thing is last year it was a lot of foundations, like this is how a bond is made and this is what an electron is and this is what it does, kind of like math basics, kind of like if you were really smart in high school you do this stuff… just making solid foundations was kind of last year, because that was freshman year. Sophomore year is then applying as in like if you have all these molecules like this, what's the structure going to be? [Sonia, Year 2, Commuter University]

On the other hand, some students at City University, who already were introduced to chemical engineering through their first-year course, commented that they were starting to relate to the material introduced to them on a deeper level by building on what they had learned in the first year. The following examples illustrate this phenomenon:

It’s obviously a lot more in depth, but it does have the core understandings from first year. So, I can see that it is being built upon. We learned something in first year, and now in second year, you’re taking that basis and you’re going further into it. [Nevin, Year 2, City University]

> *The level of difficulty has definitely increased but the nice thing about it though is it's becoming more specialized, so I'm starting to enjoy it a little bit more where I'd say in first year it was more… Well, you've just got to do the math and understand basic principles and you couldn't quite see how those apply. But now that we're getting more in depth you can… It's easier to determine what field I would like. [Naomi, Year 2, City University]*

4.2 Curricular choice

The second form of curricular difference evident in our analysis is curricular choice. Curricular choice takes two forms in the programs studied: specializations and electives. Specializations (sometimes called technical streams or degree tracks) allow students to focus their overall curriculum on a specified technical area within the field of study. The choice of specialization, usually made in the second or third year of study, determines the curricular requirements for the remaining semesters. Specializations are frequently interlaced with prerequisite requirements, meaning that students may not be able to easily switch to a different specialization. Two of the programs studied here (City & Commuter) incorporate specializations into their chemical engineering degrees, allowing students to choose subject sequences in biotechnology, minerology, environmental sustainability, or traditional chemical engineering topics.

Electives, by contrast, allow students to select classes according to their preference and schedule from a list of electives that meet some requirement, which could be specific ("choose two of the following five technical subjects") or general ("any three credit-hour class"). However, electives are differentiated from specializations in that a choice of a particular elective places little or no restriction on a student's subsequent elective choices. Three institutions, City, Residential, and Commuter include electives as part of the chemical engineering curriculum. In contrast, Town University offers no choice of electives to students. For the purposes of this analysis, classes chosen from a specialization-specific list are treated as part of the specialization while classes chosen from a list available to other specializations are categorized as electives.

Table 3 presents the percentage of the degree that students can choose as either specialization or electives. Note that these percentages are calculated based as the fraction of the total degree credits that are subject to students' choice to the total credits required for the degree. The diversity of curricular choice exhibited in Table 3 is quite remarkable, showing differences in both national and institutional approaches. As can be seen in the table, there are at times more intuitional differences within the same country than there are differences between intuitions across national borders.

Table 3: Proportion of curricular choice in chemical engineering curricula

Institution	Specialization	Elective	Combined Choice
Town	0.0%	0.0%	0.0%
City	7.5%	14.3%	21.8%
Residential	0.0%	20.3%	20.3%
Commuter	18.6%	24.0%	42.6%

As electives and specializations generally started appearing more in the third and the fourth years of the degree, we did not find a lot of instances in the first- and second-year student interviews that related to students' choice of courses. However, there were individual students who had taken a few elective courses early on in their degree and chose to talk about those courses in the interview. For example, Nicholas at City University discussed about taking a gender studies elective in his first year. He noted how taking this elective is shaping him into a person who is more accepting of people from diverse backgrounds.

> *I am very accepting of people. I do realize that [prejudice and discrimination against people] happen and [it is important] to be able to look out for that and to check myself. I think doing gender studies is also helping a lot in this regard. [Nicholas, Year 1, City University]*

The same student also discussed the influence of this elective during his second-year interview. He noted that taking a course with humanities students made him debunk the stereotype that engineers are socially reclusive and realize that engineers are not very different from other professionals in their social interactions.

> *My mom always talks about engineers as a stereotypical, very recluse, and socially... Not very socially equipped, but well orientated towards maths and that kind of brain. I find that's... I did do gender studies, so I was in a humanities class at least for a semester. And I feel that the engineers I work with, they're just normal people. I don't really see them as that different. [Nicholas, Year 2, City University]*

4.3 Contact time

The third major area of curricular difference between the institutions was time that students spent in class attending lectures, tutorials, or practical sessions. Figure 1 shows the weekly contact hours for students at the four institutions. As can be seen from the figure, while there are national differences in the weekly contact time, one could also see institutional variations within the same country.

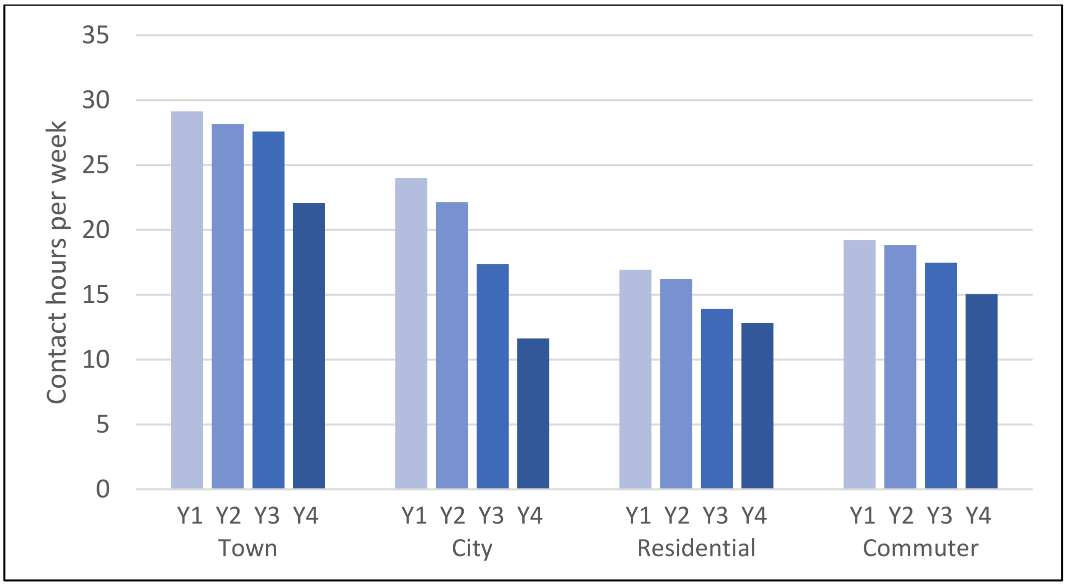

Figure 1: Average weekly contact time in each year of the curriculum (Y1 = first year, etc.)

The national differences appear in terms of the contact time in the first two years of study. For South African students, the contact time in the first two years is substantially higher than their counterparts in the United States, as shown in Figure 1. The two South African institutions also show a notable reduction in contact time in the fourth year, attributable to the large research and design projects in the fourth year. In fact, the weekly timetable documents suggest that as much as a third of the fourth-year contact hours at Town University are expected laboratory work time rather than traditional contact sessions (not evident in the figure).

With respect to the institutional variations, Figure 1 shows that in the last two years, there is a significant difference in contact time at the two South African universities, with the contact hours at City University considerably lower than those at Town University. The contact time at City University in the fourth year of the degree is even lower than the fourth-year contact time at the two US universities.

In order to provide a consistent picture of the students' formal academic interactions, this analysis is based on the weekly class schedule. Institutional differences in class scheduling, assessment structures, and contact time format make cumulative totals difficult to compare. For example, the differences in semester length (12-13 weeks in South Africa vs. 15 weeks in the US) and whether assessments take place outside ordinarily scheduled contact time can lead to variations in total contact time between and within institutions that may not reflect the students' perception of that contact time. The weekly basis is chosen both because it illustrates a student's ongoing experience of the academic timetable (as seen in the interview data), and because it provides the most consistent snapshot between the various institutional approaches to class scheduling.

Weekly contact time is based on the university's official documentation in the form of class schedules, timetable rules (e.g., period length and intra-period breaks), and degree requirements. While some instructors and some contact sessions presumably deviate at times from the official schedules, it is assumed that deviation from the official documentation is an aberration rather than standard practice.

At most institutions, the class schedule and prerequisite structures allow students to take some classes in whichever year or semester is compatible with the students' preference and schedule. This curricular flexibility also allows students who have failed (or failed to register for) a subject to add that subject in another semester. However, all the institutions in this study provide recommended or typical allocations of classes to semesters, and these published forms of the program are used in our analysis.

Specializations and electives complicate the analysis, as students may choose classes with different contact times. This analysis estimates contact time values by averaging the contact time requirements for each of the specialization or elective options whenever the options are specified. When electives are unspecified (e.g., "any 3-hour subject outside engineering"), the contact time is estimated by sampling possible subjects and choosing representative values.

The higher number of contact hours at the South African universities, especially in the first two years of the degree, gives them relatively less time outside the class than their US counterparts. As reflected in one of the student quotes from Town University:

> *Tuesdays are very chilled. Start at eight, finish at twelve or one, I think, and then that's it. We don't have a practical or a tut on Tuesdays. We have the Tuesday afternoon off, so we can study or catch up with friends. [Tiaan, Year 2, Town University]*

Here, Tiaan talks about the time other than contact time in terms of ‘free’ time: ‘free periods’ (in the morning) and the ‘free afternoon’. He actually uses the term ‘chilled’ to describe aspects of his schedule, firstly for the one day in the week where there are no scheduled sessions in the afternoon. Tiaan continued:

> *Wednesdays are fairly chilled as well. We’ve got two free periods and then we’ve got a maths and energy balances tut from two until five. On Thursdays I only start at nine, as opposed to eight, so that’s nice. We have chemistry prac in the afternoon. Fridays we’ve got a fluid mechanics prac, and again, we only start at nine. So, it’s fairly nice. In the afternoons, non-academic related, I’ll generally just chill for a bit, do work. [Tiaan, Year 2, Town University]*

Not only does Tiaan describe Wednesdays also as ‘chilled’ because of two ‘free periods’ in the morning, but he uses the word ‘only’ for the Thursday and Friday schedules because the first lecture is at 9am rather than 8am. It should be emphasized here that in comparison to the typical class schedule of a student at Residential or Commuter, this schedule is significantly more demanding of students.

Similarly, the weekly schedule of a student carrying a full load in the second year of the chemical engineering program at City University looks quite busy. As noted by one student:

> *Pretty much from Monday to Friday, I have a full day from eight o’clock to either four or five in the afternoon with a two-hour lunch break from twelve to two. Except on Mondays, I start at nine o’ clock [on Mondays]. So, from eight to twelve in the morning, it’s lectures… chemical engineering, biotechnology and maths. And then afternoons, Friday and Monday, there’s three hours of more chemical engineering. Tuesday is a biotech tutorial or practical, Wednesday… it’s either you’re free or you have a chemical engineering practical, and then Thursday’s a maths tutorial in the afternoon from two until four. [Nina, Year 2, City University]*

On the other hand, a typical weekly class schedule for a student carrying a full-time load at the two US universities seems a lot more relaxed as suggested by the quotes below:

> *Yeah, I definitely feel like there's definitely a lot more time outside of class, just in general. For most of my classes, we meet twice a week, so definitely a lot more time on my own with that kind of material. [Drew, Year 2, Residential University]*

> *I definitely spend more time outside of class than in class because we have classes for three hours per class a week. So I end up spending like fifteen, twenty hours for that one class outside of it. So definitely more outside of class. [Liliana, Year 2, Commuter University]*

A busy class schedule for students allows for little engagement in extra-curricular activities at the South African universities. When asked if they had joined a professional group or society related to chemical engineering, several students at City and Town replied that they had not. When probed for a reason, many at Town University noted that they were not aware of any professional group related to chemical engineering. At City University, while some students were aware of the presence of one group related to engineering and some had even joined it, it was difficult for them to make time from their busy class schedules to actively participate in the group. On the other hand, students at the two US institutions discussed a higher level of engagement in extra-curricular activities during the interviews.

5. Discussion & Future Work

In this paper, we set out to compare the undergraduate chemical engineering curricula at four universities – two in South Africa and two in the US, and explore the influences the different curricula have on students' experiences and thus their formation as engineers. With respect to the curricula, where we provided a comparison of the full degree structures, our findings suggest that the curricular structure at an institution is a result of an intersection of both institutional and national requirements and practices. The results demonstrate that while some curricular features may be consistent within a national context, there still are significant differences between institutions in the same country. Interestingly, there are also similarities in curricular approaches across national lines in areas where there are differences across institutional lines within the same country. Thus, our findings confirm that while being a part of the Washington Accord, the curricula under study meet the same outcomes, they are quite different in nuanced details. Our analysis also highlights some of these nuanced details.

In terms of how the curriculum influences the formation of students as engineers, this paper focuses on data from the first two years of student interviews. Our findings show preliminary evidence of how the specific structure of the curriculum and the choices it affords to students can have a significant impact on students' experiences in the degree. As our analysis demonstrates, an early exposure to content specific to chemical engineering can lead to an early identification with the discipline and the profession. However, a common first year allows students to relatively easily move from chemical engineering to a different engineering discipline. Similarly, our findings highlight how an ability to choose elective courses can allow a student to explore diverse academic interests leading to the development of diverse skills and worldview. Also, our results suggest that a relatively busy class schedule may lead to a perception that students are overworked and do not have time to engage in anything other than academics. On the other hand, a relatively free weekly schedule can afford students with the time to explore various extra-curricular avenues. All these choices that are afforded by the curricular structure and exercised by students may lead to differences in the formation of students as engineers.

Building up on this work, we plan to further explore how curricula shape students' experiences and lead to their formation as professionals. At the next stage, we plan to analyze the interviews done with the participants of this study in their third and fourth years of the degree. Also, we would like to extend the curricular comparison to engineering programs in a third country. The original study, of which this paper is a part, tracks students in three countries – the UK, South Africa, and the US. For the next stage, the curricular comparison can involve all the three countries. Finally, we plan to explore differences in curricula and resulting student experiences across disciplines. Prior work (e.g., see [18], [19]) has highlighted significant disciplinary influences on teaching and learning practices in an academic department. To study these disciplinary differences on academic curricula, we would like to do a curricular comparison between chemistry and chemical engineering programs at the participating institutions in this study. We hope that this body of work will provide engineering educators with several informed choices about structuring of curricula and the influences that each curricular structure has on students' formation as engineers.

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References

[1] National Academy of Engineers, *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, DC: National Academies Press, 2005.
[2] L. H. Jamieson and J. R. Lohmann, “Creating a Culture for Scholarly and Systematic Innovation in Engineering Education: Ensuring US engineering has the right people with the right talent for a global society,” American Society of Engineering Educators, 2009.
[3] L. H. Jamieson and J. R. Lohmann, “Innovation with impact: Creating a culture for scholarly and systematic innovation in engineering education,” American Society of Engineering Educators, Washington DC, 2012.
[4] R. Graham, “The global state of the art in engineering education,” *Mass. Inst. Technol. MIT Rep. Mass. USA*, 2017.
[5] R. Morgan and S. Ion, *The universe of engineering: A call to action*. Royal Academy of Engineering, 2014.
[6] J. M. Case, “The historical evolution of engineering degrees: competing stakeholders, contestation over ideas, and coherence across national borders,” *Eur. J. Eng. Educ.*, vol. 42, no. 6, pp. 974–986, 2017.
[7] International Engineering Alliance, “A History of the International Engineering Alliance and its Constituent Agreements: Toward Global Engineering Education and Professional Competence Standards,” 1, 2015.
[8] J. Lucena, G. Downey, B. Jesiek, and S. Elber, “Competencies beyond countries: The re-organization of engineering education in the United States, Europe, and Latin America,” *J. Eng. Educ.*, vol. 97, no. 4, pp. 433–447, 2008.
[9] S. Chandrasekaran, A. Stojcevski, G. Littlefair, and M. Joordens, “Accreditation inspired project oriented design based learning curriculum for engineering education,” in *IETEC 2013: Enhancing Global Engineering and Technology Education: Meeting the Future: Proceedings of the 2nd International Engineering and Technology Education Conference 2013*, 2013, pp. 1–11.
[10] J. Jawitz, N. Marais, and H. Hanrahan, “Using accreditation to drive curriculum development in engineering,” *Australas. J. Eng. Educ.*, vol. 9, no. 2, pp. 137–146, 2001.
[11] G. L. Downey *et al.*, “The globally competent engineer: Working effectively with people who define problems differently,” *J. Eng. Educ.*, vol. 95, no. 2, pp. 107–122, 2006.
[12] B. E. Seely, “The other re-engineering of engineering education, 1900-1965,” *J. Eng. Educ.*, vol. 88, no. 3, p. 285, 1999.
[13] J. M. Case and D. Marshall, “Bringing together knowledge and capabilities: a case study of engineering graduates,” *High. Educ.*, vol. 71, no. 6, pp. 819–833, 2015.

[14] M. S. Archer, *Structure, agency and the internal conversation*. Cambridge University Press, 2003.
[15] J. M. Case, *Researching student learning in higher education: A social realist approach*. Routledge, 2013.
[16] P. Ashwin, “Higher education is about transformation,” *University World News*, Apr. 13, 2019. https://www.universityworldnews.com/post.php?story=20190408084550435&fbclid=IwAR2xSej6jo_tGvXiZT6DtTW0nklRDan4mMA9ffgepgLgyLZt64WDb0CFpD0 (accessed Apr. 25, 2019).
[17] N. Pitterson, J. Case, A. Agrawal, and K. Krost, “National, disciplinary and institutional influences on curriculum: A preliminary exploration across two Washington Accord countries,” in *Proceedings of the Eighth Research in Engineering Education Symposium*, Cape Town, South Africa, 2019, vol. 1, pp. 607–616.
[18] A. Agrawal, C. J. Groen, A. L. Hermundstad Nave, L. D. McNair, T. L. Martin, and M. C. Paretti, “Overriding tradition?: An initial exploration of the intersection of institutional and disciplinary cultures from the student perspective,” in *2018 ASEE Annual Conference & Exposition*, Salt Lake City, UT, Jun. 2018.
[19] J. J. Lee, “The shaping of the departmental culture: Measuring the relative influences of the institution and discipline,” *J. High. Educ. Policy Manag.*, vol. 29, no. 1, pp. 41–55, 2007.