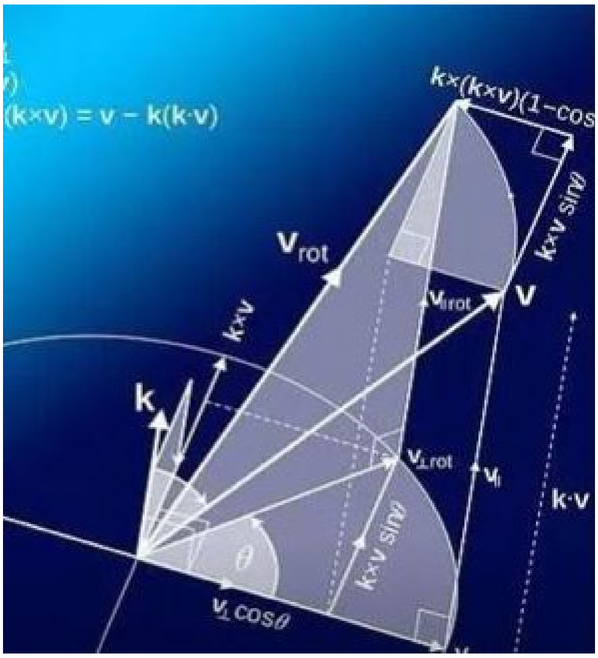


2021 DMISRS Symposium

First year mathematics: From crises mode to the new 'normal'

August 2021

Contents

Introduction

The 2021 DMISRS symposium was held online on 26 July. The symposium consisted of eight presentations and two keynote addresses centred around the theme: *first year mathematics: from crises mode to the new 'normal'*.

This report presents a detailed account of these presentations and discussions, and highlights key themes and conclusions along the way. Themes that emerged across presentations and discussions include:

- The importance of placing students at the centre and aligning teaching strategies with students' academic needs and circumstances;
- The critical role of formative diagnostic data in lieu of the above;
- The challenges involved in online student assessment; and
- The myriad of technological innovations and practices that can effectively support student engagement and the online learning environment.

Feedback provided by some of the symposium attendees was positive overall, suggestive of the value of collaborative events such as this one. This feedback is summarised in the final chapter of this report.

Introduction to the Diagnostic Mathematics Information for Student Retention and Success (DMISRS) Project and Symposium by Mr Robert Prince

Mr Prince welcomed attendees to the 2021 DMISRS symposium, highlighting the theme of the symposium: *from crises mode to the new 'normal'*. He emphasized the ever-changing nature of our current circumstances and the impact this has had on our classrooms.

Mr Prince introduced the DMISRS project; a collaborative project which aims to analyse the curricula of first-year Mathematics courses in Higher Education in order to establish how best to address students' needs through curriculum-integrated support initiatives, including blended learning.

Mr Prince explained how the project will benefit academics, higher education institutions, and students:

- It will enable academics to leverage the diagnostic potential of the provided information in addressing the needs of their particular students.
- Individual student reports will enable academics to address the mathematical diversity in a programme rather than follow a one-size-fits-all approach to teaching and learning.
- The information resulting from the analysis could be used by institutions as a tool for student placement and support and to establish curriculum-integrated support initiatives.
- It will enable academics to make evidence-based decisions for curriculum change to enhance student success.
- It will enhance curriculum support in mathematics to increase student participation and success in mathematics.
- It has the potential to change the profile of students succeeding in mathematics.
- It will enhance the first-year experience and reduce attrition.

Mr Prince presented news of the DMISRS project: it has been extended until the end of 2022 and has procured funding for NBT mathematics testing of NSFAS eligible students. Furthermore, the project has funding for student tracking. Interested parties may contact Mr Prince or Mr Balarin: robert.prince@uct.ac.za ; emlyn.balarin@uct.ac.za.

Keynote Address: Mathematics for All: Building a Social Compact by Prof. Ahmed Bawa

Prof. Bawa began his address by discussing the 'stress tests' that universities have faced since 1994, beginning with the issue of insufficient financial aid. As universities currently face a funding crisis, this lasting issue is yet to be resolved and the impact of the current crisis is still to be felt. Between 2015 and 2017, student activism (including Rhodes Must Fall and Fees Must Fall) highlighted deep structural issues in higher education, and called for a new philosophical approach to mend what Prof Bawa called "*a broken social compact*". These disruptions challenged the dominant knowledge project in higher education, such as a growing move toward the decolonisation of curricula. The most recent stress test faced by universities is the COVID-19 pandemic, and the rapid shift to emergency technology use – the implications of which are still to be determined.

Prof Bawa noted several important lessons that have surfaced in light of the pandemic:

- **Partnerships and collaboration** have been essential for the completion of the 2020 academic year. Despite the historical differences between universities, there was significant collaboration among institutions which generated "*a lot of hope that we can move into the new era*".
- There is a need to **focus on students**, including: who they are and what their socioeconomic circumstances are; what skills and knowledge they already have; how they access materials; and what support they need. In order to succeed, universities need to design their programmes around this student-centric information.
- **Institutional innovation** has been critical to rapidly respond to problems, and will likely be a recurring theme as we navigate the future.
- The **repurposing** of budgets, research, teaching, etc helped universities cope with the pandemic.

Prof Bawa went on to discuss some of the conditions unique to South Africa that have implications for the ways in which we think about ourselves and our educational context, such as:

- Co-existing and co-inhabited knowledge systems;

- South African languages, many of which are underrepresented in our universities;
- A major chasm between research and innovation;
- The rigid discipline-based organisation of universities;
- The balkanisation of knowledge domains;
- Race and gender imbalances in our scholarly community;
- The need to foster epistemic access, or "*bridges*" for students;
- A lack of systems for evidence-based interventions;
- A lack of attention paid to what learning experiences take place outside of the classroom at universities (a "*dishevelled second curriculum*"); and
- 'Verwoerd's legacy': many children do not have access to mathematics.

Prof Bawa posed the question: where does mathematics fit into *all* of this?

Prof Bawa went on to present some familiar, yet sobering, statistics that illustrate the "leaking pipelines" in our mathematics throughput rates, and the unequal picture of mathematics achievement. He argued that these issues represent a political economy issue as a substantial number of young people are unable to enter into the economic trajectory. This further entrenches racialised and class-based inequalities on a year-by-year basis, undermining social transformation and deepening our failure to build and strengthen a knowledge economy.

While the purposes of higher education are generally geared toward public good, such as nation-building and creating active citizens, Prof Bawa argued for the objective of building a new cohort of intellectuals. In this vein, mathematics helps students to develop critical skills such as problem-solving, systemic thinking, critical thinking, teamwork, ethical reasoning, etc.

When conceptualising the basis for a new national knowledge project, Prof Bawa reflected on the notion of mathematics as foundational to society. From the beginning, he noted, mathematics has been finely interwoven into our colonial and apartheid histories. Today, children are directly oppressed through their exclusion from mathematics scholarship, an issue which needs to be urgently addressed. By building generations of intellectuals, the nation can be rid of its shackles of oppression. A nation that is schooled in the skills of rational thought and logic can confidently contend with the challenges of the future – skills that are cultivated through mathematics. As such, Prof Bawa argued that this is as much a political project as it is an education one, saying:

"*Every young person that enters school should do 12 years of mathematics because it's not simply about getting into the STEM subjects, it's also about strengthening our democracy and strengthening our ability to address the big, grand challenges that we face in our society.*"

Prof Bawa closed his address by discussing a proactive way forward. Reflecting on the pandemic, he noted the critical importance of developing partnerships and collaborative relationships among universities, noting the value of the DMISRS project in this vein. He argued that there is a need for a national conversation, led by the president, about a new imagination for basic education – an all-encompassing social compact that places children at the centre. There should be a sustained and concerted effort to ensure that children grow and reach their fullest potential. Prof Bawa went on to argue that the basic education system should be shaped by the imperatives of social justice, nation-building and social cohesion, and that mathematics should be seen within this broader context. Only in recognising this role of mathematics, can we "*decisively free ourselves from the Verwoerdian paradigm*".

QUESTIONS FROM THE AUDIENCE

Q: How does a focus on pass rates affect schools' ability to achieve?

A: Pass rates are a poor way to measure the efficacy of our education system. In South Africa, we have too great a focus on pass rates at the expense of an explicit understanding of what our basic education system should achieve. This reflects the need for a new national conversation around the social compact, and a concerted effort to establish what exactly we want from our basic education system.

Q: What are your thoughts on the growing shift among schools to encourage children to take up mathematical literacy?

A: The issue of mathematical literacy is a national challenge, and we

The Effect of Taking a First-year Discrete Maths Module on Performance in Second-year Mainstream Mathematics by Dr Washeela Fish

Dr Fish began her presentation by noting the lack of research regarding the transition from first-year to second-year mathematics, despite the number of second-year interventions that have been designed to address the issue of transition. As such, Dr Fish presented the results of an examination into the effect of a first-year discrete mathematics module on student performance in second-year mainstream mathematics (by W. Fish, R Blignaut, A. Engelbrecht, and K. Kekesi).

Dr Fish discussed the *articulation gap* – the mismatch between exit-level school education and entrance level higher education. Gaps in skills and knowledge present in the classroom as students engage superficially with texts and are disinterested in reading to develop a greater understanding of concepts. Students also show a preference for surface-level learning, preferring to memorise theorems rather than making an effort to understand them. Dr Fish argued that the South African school sector cannot be relied upon to close the articulation gap on its own, with universities shifting toward a greater emphasis on teaching and learning, as well as student support interventions.

Dr Fish went on to discuss the different, and more challenging, requirements that students face in their second year of mathematics as they begin to engage with more advanced content. She highlighted a number of gaps in second-year skills and knowledge, including:

- A perception of mathematics as purely algorithmic, due to the emphasis put on computations in first-year mathematics;
- A lack of sufficient exposure to theorems and propositions;
- Students are often unable to justify, interpret, explain or evaluate numerical answers in written language;
- A failure to realise the significance of definitions;
- A lack of sufficient knowledge about direct proof, proof by contraposition, proof by contradiction and induction;
- Students are often unable to distinguish between logically valid and invalid arguments;
- Misconceptions about the role of counter-examples in relation to disproving existential statements;
- A lack of understanding of conditional statements and their converses, inverses, contrapositives, and negations.

Dr Fish then posed the question: how do we go about solving this problem of gaps in foundational skills and knowledge?

In pursuit of an answer, Dr Fish described a first-year intervention in the form of a discrete mathematics module ("Module 1") that was introduced to provide some of the foundational concepts that are needed for second-year mathematics. Module 1 incorporated: an introduction to propositional and predicate calculus; sequences; mathematical induction; and elementary set theory and number theory. In previous years, a follow-up module was offered which incorporated: relations; functions; cardinalities; combinatorics; and graph theory. Module 1 was not compulsory to proceed to second-year mathematics.

Dr Fish described the "corridor talk" that took place as the impact of Module 1 began to materialise. Lecturers began to notice that students who completed Module 1 were doing better in second-year mathematics compared to those who elected not to take the course. Furthermore, course evaluations indicated that students found Module 1 to be helpful in terms of mastering second-year work. Consequently, Dr Fish and her colleagues decided to analyse the Module 1 results in relation to second-year pass rates from 2012 to 2019. As can be seen in the table below, the pass-rate for the students who took Module 1 far exceeded those who did not take the course. Average and median course results were also found to be greater for the Module 1 students, with hypothesis testing indicating significant differences among the two student groups in all years except 2014 and 2017.

Table 1. Pass rates for second-year mathematics among Module 1 students and non-Module 1 students.

Year	No. of students (overall)	No. of students (Module 1)	No. of students (Non-Module 1)	Pass rate for Module 1 group	Pass-rate for Non-Module 1 group
2012	99	13	86	92%	75%
2013	97	20	77	60%	30%
2014	119	4	115	75%	67%
2015	111	12	99	75%	45%
2016	116	13	103	85%	46%
2017	141	8	133	38%	32%
2018	168	18	150	89%	69%
2019	126	21	105	90%	69%

These analyses helped to determine that taking the Module1 course had a positive effect on students' performance in second-year mainstream mathematics.

Key Points

- **While content and teaching strategies likely play an important role, there is support in the literature for focusing on the content, and thus having a module, such as Module 1, as a prerequisite or a co-requisite for students in mainstream mathematics.**
- **If this is not feasible, the core content of first-year discrete mathematics can be incorporated into first-year mainstream mathematics**

The Role of School Mathematics Olympiads/Competitions in Preparing Learners for Mathematics Oriented Programmes/Courses at University by Dr Vasuthavan Govender

Dr Vasuthavan Govender is the regional coordinator of the South African Mathematics Team (SAMTC) competition and senior team coach. Dr Govender began his presentation by highlighting the importance of both primary and high school teachers understanding why mathematics should be studied:

- Mathematics provides the quantitative and logical structure, as well as strategic thinking, that underpins many important fields of study (e.g., information technology, finance, engineering, research and teaching).
- Mathematics is stimulating and challenging, and helps students develop problem-solving and logical reasoning skills. It helps to produce more citizens who can learn and think creatively and critically, regardless of their career fields.

Dr Govender noted a statement by Prof Johann Engelbrecht (former executive director of SAMF), saying that the top students in the South African Mathematics Olympiad (SAMO) perform well at university. This is because the type of problems that students face during the SAMO is similar to what is expected at university level. Furthermore, participation in mathematics competition helps students develop critical thinking and problem-solving skills, which are important for succeeding at university and in the marketplace.

In 2018, Dr Govender conducted a survey of the Grade 12 SAMTC students and asked them about their career choices. There was a substantial emphasis on problem-solving as the students gave their reasons for their choices, such as computer science, medicine, engineering, actuarial science, and psychology.

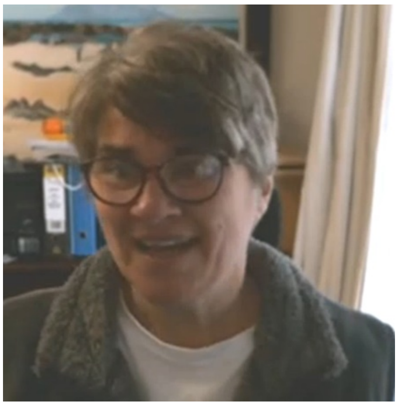
In preparation for the DMISRS symposium, Dr Govender interviewed six students who matriculated between 2019 and 2020, and had a history of participating in Olympiads in both primary and high school. When asked how the Olympiads impacted on their school mathematics, the students said that they were introduced to concepts earlier on than they would have encountered them at school, were better prepared, developed better problem-solving skills, and that the Olympiads helped them work better and more efficiently in school mathematics.

When asked how the Olympiads helped to prepare them for university, the students noted that they were more familiar with university-level questions having been exposed to them at a younger age by the Olympiads. Furthermore, the Olympiads helped to cultivate a sense of discipline, diligence and "relentless effort" that familiarised students with doing extra work and equipped students with the attitude and stamina to not give up in the face of difficulty.

Key Points

- **Participation in mathematics school competitions and Olympiads gives most learners ad advantage as they transition to university. As such, we should encourage schools to take up competitions and Olympiads in both primary and high school.**

Employing Mathematics to Investigate how Undergraduate Engineering Students Experience Critical Thinking by Ms Liezle Boshoff



In her presentation, Liezle Boshoff shared the details of her PhD research study: *a phenomenographic investigation into how engineering students experience critical thinking*. She began by explaining the background to this investigation, noting that engineering students need critical thinking skills for proper engagement with their studies, but few have these skills. Furthermore, engineering lecturers find it difficult to teach critical thinking skills and some may not have these abilities themselves. Ms Boshoff outlined the specific research problems informing her research: (1) there is a lack of discipline-specific definitions of critical thinking; (2) critical thinking needs to be discerned from similar activities (e.g., problem-solving and creative thinking); and (3) it is difficult to determine *how* students think. This led Ms Boshoff to her research question: *what are the qualitatively different ways in which engineering undergraduates experience critical thinking?*

The nature of this question lends itself to phenomenography – the qualitative study of the different ways in which people experience a phenomenon. With regard to Ms Boshoff's research design, her sample consists of 15 second-year engineering students from CPUT. The students engaged in a day-long mathematical activity (individually) which Ms Boshoff designed to afford students the opportunity to apply critical thinking skills. Ms Boshoff then conducted virtual semi-structured interviews to understand the students' experience with the activity.

The activity took the form of math modelling, which was chosen due to its ability to help document student thinking. Modelling requires complex thinking using simple mathematics – the focus is on students' thought process, as opposed to subject matter. Lastly, students are required to structure a situation in terms of mathematical relationships rather than simply translating (as in traditional word problems).

To analyse the student qualitative data, Ms Boshoff described the Martonian approach, an iterative process that involves: (1) searching for meaning statements; (2) grouping similar meaning statements together; and (3) looking for themes and categories of description.

Ms Boshoff noted an important limitation in her study, and others that attempt to study such a complex phenomenon. The complexity inherent in critical thinking means that Ms Boshoff's ability to investigate it thoroughly will be limited by her own interpretation of critical thinking.

Ms Boshoff closed her presentation by highlighting comments by Sandra Egege – an author on critical thinking: too little is known about how critical thinking could be developed in mathematics and engineering – a gap that will be addressed by Ms Boshoff's research.

Key Points

- **The single most important factor influencing the development of students' critical thinking is their *current* ways of experiencing critical thinking.**
- **If lecturers better understand how students experience critical thinking, they might be able to better explain and teach these skills, and design appropriate activities.**

Relating Profile to Performance in Engineering Mathematics: A Quantitative Case Study by Ms Anita Campbell, Dr Pragashni Padayachee & Ms Precious Mudavanhu

In her presentation, Anita Campbell presented a research study that she conducted alongside Pragashni Padayachee and Precious Mudavanhu to answer the following research question: *how can the analysis of student data contribute to understanding student performance in Calculus?* The objective of this research was to better understand the engineering students that these researchers teach so that their teaching would be better aligned to students' needs.

The research drew on National Benchmark Test (NBT) data from 2015 to 2018 (n = 731). The sample was predominantly South African and male. Just over half of the sample (56%) speak language as a second language. Students belonged to an academic support programme for engineering, where they begin their studies on the four-year programme and can later choose to move into a five-year programme in which the first year is spread over two years.

Looking at Calculus 3 results, analyses revealed that female students tended to slightly out-perform male students, and there was no significant different between students from different countries. Moreover, those who speak English as a second language slightly out-performed those for whom English is their home language.

To explore further, the researchers conducted a relative importance analysis, measuring how changes in NBT results influence the Calculus 3 results. As expected, the most important explanatory factors for overall Calculus 3 performance are the *NBT Mathematics* domains (geometric reasoning and trigonometric functions and graphs). The researchers then explored the performance of students achieving the top marks (75%+) in Calculus 3, finding *academic literacy* to be the most important explanatory factors (particularly grammar, text genre, and vocabulary) (Figure 1). Then, looking at the students who failed Calculus 3, the researchers found a Mathematics subdomain, again, to be the most important (trigonometric functions and graphs) (Figure 2).

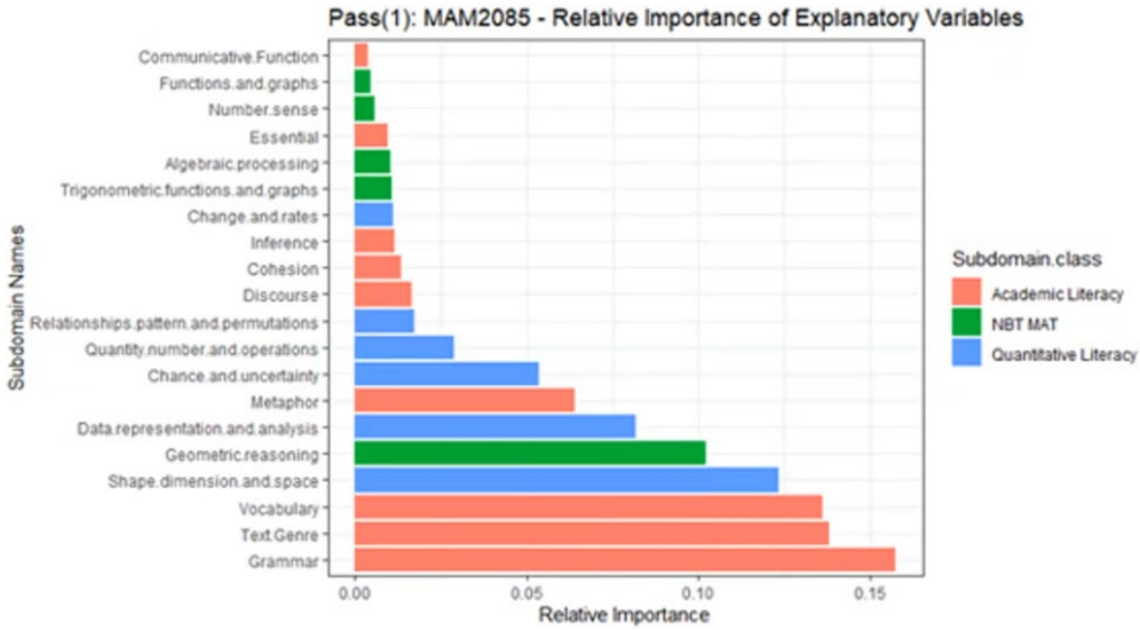


Figure 1. Relative importance of NBT explanatory factors on students achieving 75%+ in Calculus 3.

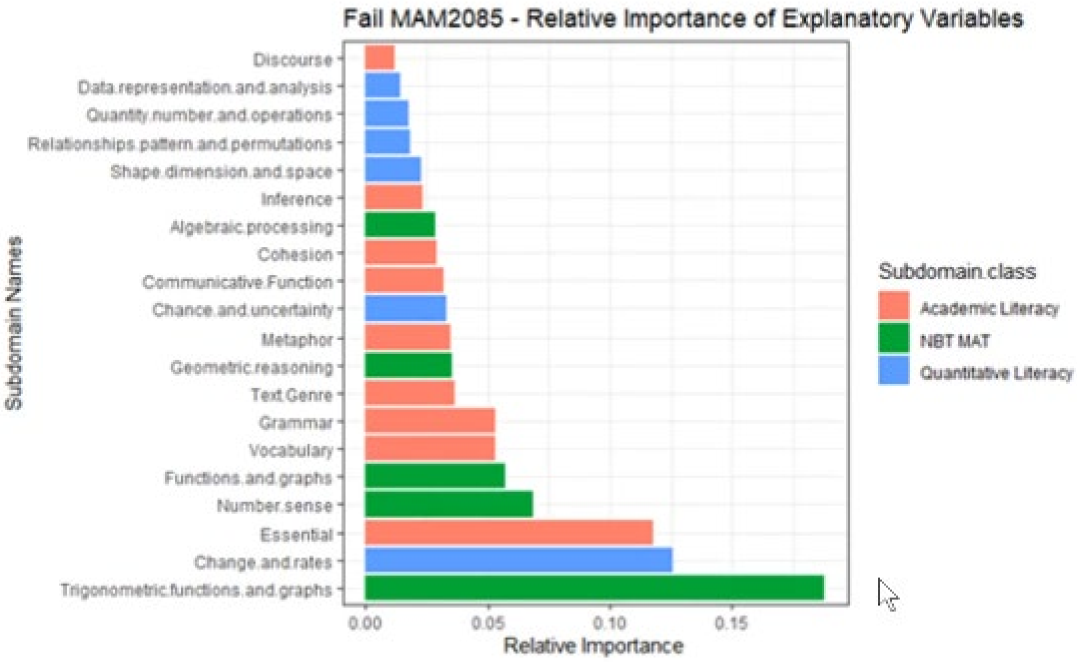


Figure 2. Relative importance of NBT explanatory factors on students failing Calculus 3.

The importance of academic literacy in these results prompted the researchers to review the related literature, as Ms Campbell noted that Calculus lecturers are not trained in academic literacy. Drawing on Moschkovich (2015), Ms Campbell noted that mathematical activity is mediated by:

- Language, signs and social activity;
- Focussing on potential for progress rather than learner deficiencies or misconceptions; and
- Going beyond "language as words" and "mathematics as numbers".

Furthermore, academic literacy in mathematics encompasses:

- Mathematical proficiency;
- Mathematical practices; and
- Mathematical discourse.

Key Points

- **Interventions to improve engineering students' performance in third-year Calculus should include developing academic literacy practices, potentially in first- and second-year mathematics courses.**

New Role of Graduate Teaching Assistants in Virtual Spaces by Ms Ekaterina Rzyankina and Mr Frikkie George

Ms Rzyankina presented current research being conducted by herself and Mr Frikkie George, of CPUT, on the role of graduate teaching assistants (GTAs) in virtual spaces. She began by noting some contextual background, including that most CPUT students are first generation degree students, and most come from past and currently disadvantaged schools. The main research question for this study is: *what is the new role of GTAs in virtual spaces at CPUT?* This question is grounded in the disruptions to teaching and learning that have taken place due to COVID-19, including: moving teaching onto online platforms; inequality among well- versus poorly-resourced students; technological challenges (e.g., lack of infrastructure); and the training of teaching assistants which is generally a face-to-face process.

In terms of research design, the study is a mixed methods investigation utilising interpretivism (in the form of case studies). Interviews will be conducted with eleven GTAs (mostly PhD students), and online feedback will be obtained from students and lecturers. Lastly, the researchers will observe online Zoom or BB Collaborate sessions.

Mr George explained nine enhanced roles that the study will investigate when it comes to GTAs in virtual spaces:

1. Assist with diagnostic support (e.g., bootcamp, diagnostic tests, identifying at-risk students, and developing diagnostic support with lecturers).
2. Use CPUT-WConline booking system which helps GTAs manage and respond to appointment requests from students. The system is also used for online consultations.
3. Conduct consultations on online platforms (e.g, WConline, Blackboard, Zoom, Teams) in one-on-one and group sessions.
4. Assist with compulsory online tutorial sessions in breakout rooms once a week.
5. Assist with online marking of formative assessments.
6. Engage with students on social platforms regarding notices and consultations (e.g., Facebook, WhatsApp).
7. Be familiar with the Blackboard learning management system, which allows synchronous and asynchronous sessions with students, as well as check-ins, content sharing, and reflections (e.g., polls).
8. Use WebAssign to assist at-risk students, select appropriate e-textbook exercises for self-study, and set tutorial questions.

9. Contribute to research outputs by identifying students' conceptual errors and collaborating with lecturers to produce journal articles.

Ms Rzyankina then went on to discuss current challenges with multimodal teaching and learning, including:

- Data and resources, especially for students in rural areas;
- Load-shedding;
- The need for digital writing pads and tablets for consultations;
- Under-utilisation of e-textbooks and WebAssign;
- Troubleshooting skills

Key Points

- **The future of teaching and learning will depend on a multimodal approach, including face-to-face and online consultations.**
- **It is important to ensure that GTAs are appropriately skilled in the virtual spaces needed for teaching and student support.**

The NBT Online Mathematics Test: Reflections and Insights by Ms Tatiana Sango

Ms Sango began her presentation by describing the experience of moving high-stakes examinations, such as the NBTs, online. Important considerations include retaining credibility and security of the tests, without compromising the validity and reliability of the results. Moreover, there are considerable concerns in taking examinations online, such as:

- Lack of access to devices and stable, secure internet connection;
- Technical issues (e.g., software compatibility and reliability);
- Students' digital education (e.g., ability to download and install packages);
- Academic dishonesty and the risk of cheating and identify fraud;
- The process of translating paper assessment items to an onscreen presentation;
- The comparability of paper and online assessments;
- Data protection and students' privacy rights;
- Not having a physical record of test completion (i.e., a 'script' as evidence);
- Adaptations to the individual needs of students with disabilities; and
- Generating reliable data as evidence of students' learning.

Ms Sango went on to describe the online administration of the NB Mathematics test in 2020 and 2021. Four MAT tests (60 items each) were conducted in 2020 and 2021, with a total of eight tests. She noted that many institutions made the NBTs optional in 2020, whereas more institutions are requiring the NBTs in 2021. As such, uptake in 2021 has been higher this year (~10500 students).

To take the test, students need to follow a three-step process. Firstly, they must complete registration and preparation for the test, then they take the test online using a secure locked browser in an invigilated environment (using microphones and webcams). Lastly, they obtain their results via the NBT website two to four weeks after taking the test.

The NBT online team had to manage a number of tasks to create and manage the online environment, including creating the testing environment, communicating with students, training staff, setting up proctoring, and managing the data.

Ms Sango described experiences with the online administration of the MAT test. A number of common threads were evident during the pre-test and in-test interactions with candidates, especially in 2020. These include: data costs, stable connectivity, digital education, shared devices, types of devices, screen size and resolution, access to functional webcams and microphones, and software versioning and licensing. Additionally, students' technical proficiency is an important factor, as well as the provision of live support to students. Lastly, invigilating the test and conducting assistive proctoring processes (e.g., preventing the students from browsing the internet) are essential elements of online test delivery.

With regard to the test delivery format, the online environment poses particular challenges to mathematics rendering, images, and diagrams. Device issues or slow internet can cause errors and interfere with the students' ability to properly see test items.

Ms Sango presented a comparison between the 2019 pencil-and-paper test and the online tests in 2020 and 2021:

Table 2. Pencil-and-paper vs online MAT results: 2019 - 2021.

MAT186	Pencil and paper 2019	MAT186	Online 2020	Online 2021
mean	37	*mean*	49	45
StDev	16	*StDev*	21	18
min	18	*min*	24	24
1st quartile	26	*1st quartile*	30	29
median	30	*median*	44	38
3rd quartile	42	*3rd quartile*	66	56
max	97	*max*	97	97
N	4 595	*N*	3 818	1 401

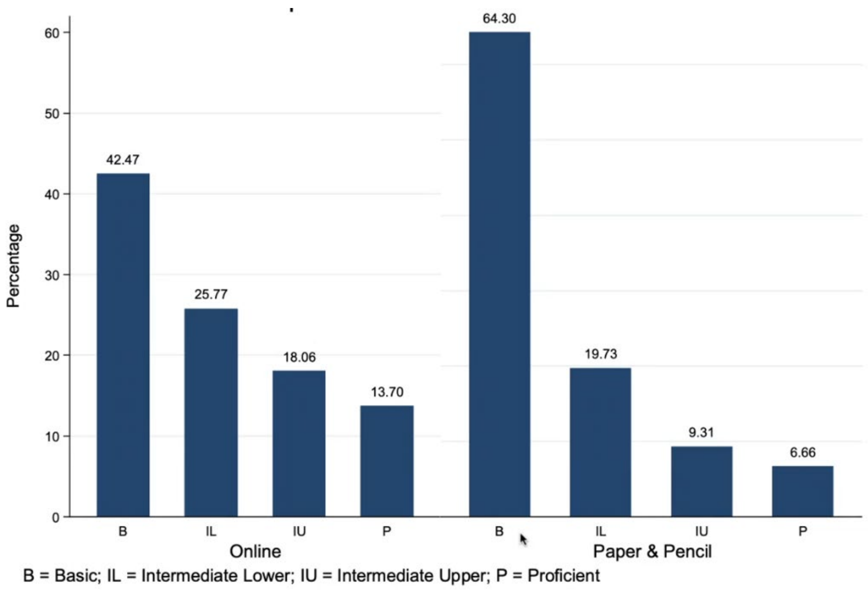


Figure 3. Mathematics performance bands: Online vs paper-and-pencil.

She demonstrated the differences between the two administrations, which show increased marks in the online versions of the test that warrant further investigation. Ms Sango noted that she and her team will be investigating the extent to which the differences between paper-and-pencil and online delivery modes are statistically significant. Preliminary results suggest that the two modes are providing different score distributions but this may be due to a myriad of factors that are not yet explored (e.g., the way in which students experienced Grade 12 and the manner in which the scores were "normed").

Key Points

- **There are a number of technical considerations and issues that need to be carefully managed when moving from pencil-and-paper tests to an online environment. For example, students need to be adequately equipped with the necessary infrastructure and digital literacy skills.**
- **NBT results indicate that the online test is associated with greater student performance which warrants further investigation.**

Captioned Lecture Recordings as a Resource for Mathematical Meaning-making by Assoc Prof Kate le Roux

In her presentation, Prof le Roux presented a project conducted in collaboration with colleagues Jeff Murugan, Stephen Marquard and Patrick Adams. Jeff Murugan (Department of Mathematics and Applied Mathematics) has been podcasting and videoing his lectures since 2006. This was taken up university-wide from 2012, supported by UCT's Centre for Innovation in Teaching and Learning (CILT). In 2019, the research team conducted a pilot project to explore the development of a cost-effective, time-efficient and automated process for producing captioned and transcribed lecture-recordings in a technical discipline (such as applied mathematics). Secondly, the pilot would investigate how students use captioned lecture-recordings in conjunction with other resources for mathematical meaning-making. The study used a convenience sample; 29 students in Applied Mathematics III – the last semester of a three-year science degree.

The pilot was to be expanded in 2020, but due to COVID-19, UCT instituted a university-wide automated process for uploading videos to the online platform (Vula). Using Google Speech, videos would be immediately transcribed and there was an option to review and edit, as well as to request manual transcription using WaywithWords (which would take 2 to 5 days).

During the 2019 pilot, the team collaborated with WaywithWords by sending them recorded Applied Mathematics III lectures. The team then developed a style sheet for WaywithWords' transcriptions, including the preferred format of mathematical language that should be used (Figure 4).

Current Use	Suggested Change
Numbers from 0 to 9.	Write out numerical value in words (e.g. one, two, three, etc.)
X1Y1, X2Y2 etc.	x-one, y-one, x-two, y-two etc. Use hyphen, not dash and with no spaces (same applies to all hyphens in this list).
end point	endpoint
F(x,y)	f of x, y
ODES	ODEs
Spatial co-ordinates like "(1,1)"	Write these out fully in words as "one, one".
resurgent	recursion

Figure 4. Example of style sheet.

To understand what resources students used, and how, the team asked a sub-sample to keep a weekly record of the resources that they had made use of that week (via a GoogleForm checklist). In focus group interviews, the team gave the students a log of their recordings and asked them to visually illustrate how they used different resources together and individually Figure 5). Lastly, students were asked how they used the captioned video recordings that were uploaded to Vula.

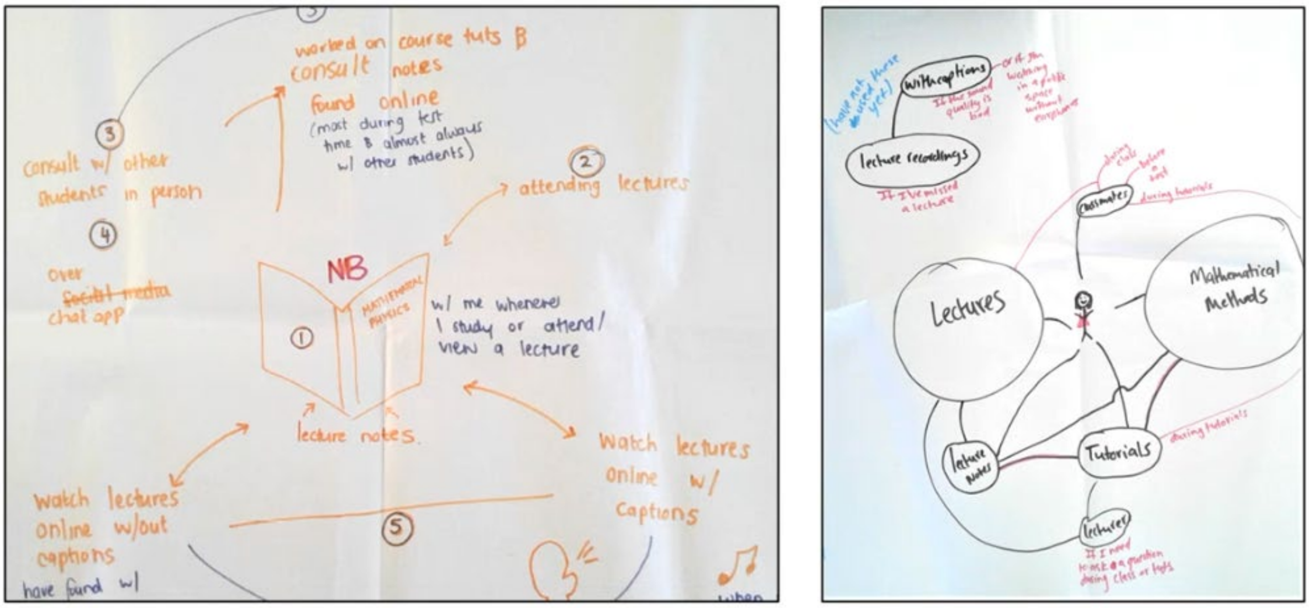


Figure 5. Examples of students' illustrations in focus group interviews.

In analysing this data, Prof le Roux used the notion of resources by Adler (2000) and Lave and Wenger (1991) which states that the value of resources lies in the *use* of a resource and its relative transparency. With regard to transparency, in order for a student to effectively use a resource for learning, the resource needs to be simultaneously *visible* (noticed, understood, and used) and *invisible* (it should facilitate meaning-making without getting in the way in terms of difficulty of use).

The qualitative findings indicated that *time* is a central resource for students; they think carefully about what time they have available for the course, and what activities and resources they will use. A second central resource were the live lectures, which the students attended regularly. The students reported valuing the clear structure of the lecture, the pace, the blackboard text, links made with the textbook, as well as the lecturer's meta-commentary on the blackboard text. The third resource that students identified were their hand-written notes that they had taken during the lecture. In terms of transparency, one student said that she takes copies of the textbook into the lecture and makes notes on these copies, rather than "trying to rush to write everything down". For another student, whose first language is not

English, language got in the way of transparency, as he struggled to understand the lecturer's explanations.

With regard to the lecture recordings, students reported watching the full recording on the rare occasion that they missed the live lecture. All students reported having used parts of the recording to supplement the notes that they had taken in the live lecture. The digital platform supported transparency as the students could change the speed of the lecture and pause as needed to process the content. The captions appeared to be a transparent resource for the majority of students, as they helped to ensure that students caught everything the lecturer said. The students noted that captions could be particularly helpful in other courses where the lecture venue was noisy, the board text is not clear due to handwriting or poor lighting, a lecturer's accent is difficult to follow, and for first-year mathematics students.

Key Points

- **Students use multiple resources in agentive, personal and contextual ways.**
- **Students value lecturer's coherently planned use of resources, with the lecture being a key resource for meaning-making (both in-person and in remote teaching).**
- **It's important to make explicit to students what resources are available, and how they can be work together or individually.**
- **It's important to make lecturers aware of the option to use captions and transcriptions, as well as their potential for use along with other resources.**
- **It is necessary to further investigate the specific resources used by students with diverse language repertoires, levels of study, and disciplines.**

Strengthening Mathematical Understanding using Learning Trajectories and Diagnostic Assessments by Meetal Shah

Meetal Shah, from the Math Door, reported on a project that she has been working on with Prof Jere Confrey on a digital diagnostic formative assessment system.

Ms Shah explained that, in the United States, teachers have limited access to data on student learning, as assessments are administered toward the end of the year. She noted important qualities of a diagnostic formative assessment, including:

- Precisely identifies students' needs and current progress;
- Flags common student misconceptions;
- Informs optimal and flexible student grouping (rather than fixed grouping);
- Provides intuitive and immediate data reports to both teachers and students;
- Promotes student agency and self-regulation through feedback;
- Provides opportunities for practice and re-testing; and
- Allows teachers to flexibly choose what to assess, when to assess it, and how much to assess, using a formative approach.

Ms Shah explained that the Math Door has built their diagnostic assessments on a foundation of research-based learning trajectories – specifically, descriptions of what students bring to instruction, as well as the landmarks and obstacles that impact students' learning of a target concept. These trajectories are conceptualised as a climbing wall, as opposed to a ladder, or singular, linear pathway of learning. Students are positioned at different places on the 'wall', and can take different pathways to reach the top (the target concept). Furthermore, different landmarks and obstacles will be present along different pathways that students take.

Ms Shah introduced The Math Door's *Math-Mapper 6-9* – a diagnostic formative assessment tool that comprises of a learning map, which demonstrates 11 'big ideas' in mathematics spanning Grades 6 to 8. On the backend is the tool's diagnostic assessment and reporting system that provides teachers and students with reports. Teachers have the option of conducting a readiness assessment before using *Math-Mapper* to assess the extent to which students are ready to learn a particular mathematical concept. Thereafter, teachers choose the content to teach and then assess the students using one of the diagnostic formative assessments. Teachers then review the assessment data individually, and then together with the students.

Assessment results are presented as a heatmap, organised from lowest-performing to highest-performing students along the horizontal axis, and from lowest to highest learning trajectory on the vertical axis (Figure 6). The heat map allows teachers to identify the trajectories that need additional revision or modified instruction, as well as the groups of students who require support or extension on the topic. Teachers can then use this data to personalise their instruction using groups or stations, and then re-test to assess the extent to which the personalised teaching was effective.

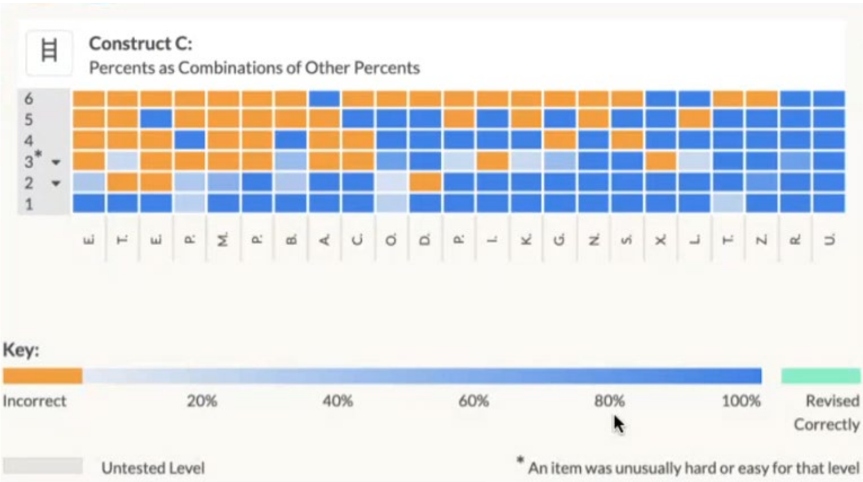


Figure 6. Example of assessment data heatmap.

Ms Shah closed her presentation by noting the importance of using formative assessment data to inform practice, revision and re-testing. This ensures that student results are pushed into the higher end of the distribution curve (Figure 7).

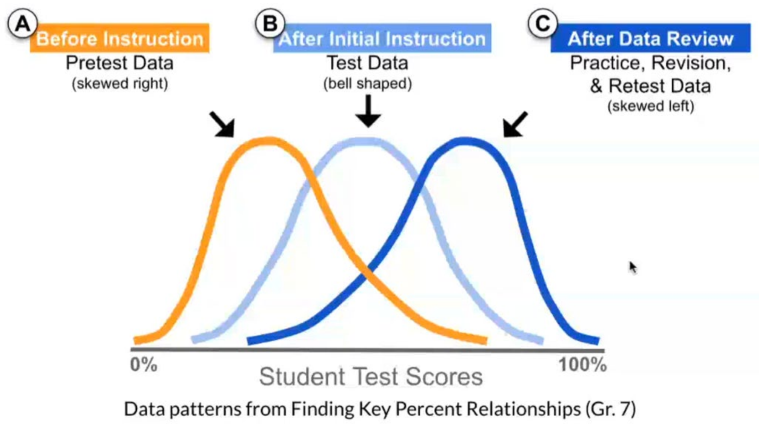


Figure 7. Data patterns before instruction, after initial instruction, and after data review.

Keynote Address: Dr Pragashni Padayachee - Teaching and Learning Mathematics during Covid 19: Reflections on a New 'Normal'

Beginning with a reflection on the effects of COVID-19 on teaching and learning, Dr Padayachee said that while the pandemic has brough substantial social inequalities to the fore, it has also stimulated great innovation within teaching and learning.

With regard to technology for learning, Dr Padayachee noted that many institutions had planned to incorporate technology into learning, but that the pandemic has meant that changes intended to occur over months and years had to be implemented immediately. While prior to the pandemic, online spaces were predominantly used for filing and storage, the pandemic "*has illuminated what can be done with this online space. It can be engaging, enriching and accessible*". Furthermore, learning is no longer a 'one-time event'; online spaces allow for a more seamless learning experience, where students can continue conversations in discussion forums and ideas can be recorded outside of classes. Students are now also able to learn at their own pace, anywhere and at any time. However, this means that access to technology and connectivity is more critical than ever, especially as a large number of students do not have access to the devices required to learn online.

As the teaching and learning environment moved online, Dr Padayachee noted how important it was to continue a shared sense of community in the online classroom. Connectedness and collaboration can be difficult to cultivate in virtual spaces, however, online forums presented a viable option to encourage interaction in place of face-to-face tutorials and class discussions. Dr Padayachee described the experience of forums in her courses: students benefitted from participation, taking comfort in knowing others were experiencing similar issues, and students could help and support each other.

A sense of community is also important for lecturers, especially considering the value of spontaneous, in-person meetings and discussions that can lead to the generation of new ideas, problem-solving and collaborations. Dr Padayachee was part of a group of four academics from South Africa and the Netherlands who formed a community of practice to research how their assessment practices changed as a result of the pandemic. In fortnightly meetings, the group shared ideas, discussed challenges and explored literature on assessment in mathematics. They also interrogated each other's work and articulated their own experiences.

Dr Padayachee explored the notion of redefining student engagement. Before the pandemic, engagement was synonymous with attendance at lectures and tutorials. Now, engagement has had to be redefined to incorporate online interactions (e.g., discussion forums and meetings), which Dr Padayachee argued better demonstrates students' engagement.

With regard to summative assessments, Dr Padayachee noted that there are few viable options to uncover or prevent cheating. Instead, many chose to focus their assessments on student learning. Dr Padayachee's community of practice identified five principles in this regard:

1. Open-book assessment has value as a way to test for mathematical understanding whilst developing fourth industrial revolutionary skills.
2. Verbalising helps learning; a portfolio of video explanations can be explored as an alternative assessment option.
3. Assessment can promote self-directed learning.
4. Assessment can develop higher-order thinking skills.
5. Assessment as learning and for mastery benefits students.

Creative assessment strategies that Dr Padayachee's colleagues implemented during the pandemic include: students recording podcasts and writing blogs; peer assessment; video assessment; and assessment of discussion forums.

As students navigated the novel online learning environment, Dr Padayachee realised the importance of flexibility and understanding, as students grappled with technical issues and limitations. For example, one of her students had to walk three kilometres everyday to get internet access. Furthermore, working from home could be difficult for students, as living spaces were crowded and noisy, and they needed to help with chores in the home. Dr Padayachee argued that this is not the time for student accountability as both students and lecturers have been taken out of their comfort zones. Rather, she stressed that "*we need to be empathic and understand the challenges that our students experience*".

Reflecting on the future, Dr Padayachee said that education is at a juncture: one path leads back to business-as-usual, while the other leads to new ideas and imperatives. She argued that "*the higher education system can emerge from this pandemic stronger than it was if it* *harnesses the lessons of virtual instruction to find more engaging, inclusive and creative ways to support, connect with, value, and unleash the potential of every student*".

Key Points

- **The pandemic has highlighted numerous innovations and opportunities for creativity in terms of the online learning environment, as well as student assessment and community-building.**
- **Along with technical changes to teaching and learning, there should also be a mental shift with regard to a greater sense of empathy for students, and reconceptualising the notion of student engagement.**

Post-symposium Feedback Survey

At the end of the symposium, attendees were asked to complete a short survey regarding their experience of the symposium. The survey results are used by the CEA team to measure the impact of their work, and to inform continuous improvement of DMISRS offerings. Twenty symposium attendees opted to provide this feedback.

This was the second time that the DMISRS symposium was held online. Regarding the effectiveness of this online format, the majority of survey respondents rated it highly, scoring it 4 (30%) or 5 (55%) out of 5.

When asked whether there was any discussion or presentation that was particularly interesting or useful, 100% of respondents said that there was. The most frequently cited presentations included:

- *Teaching and learning Mathematics during Covid 19: Reflections on a new 'normal'* by Dr Pragashni Padayachee (25%);
- *Keynote address* by Prof Ahmed Bawa (15%); and
- *Captioned lecture recordings as a resource for mathematical meaning-making* by Prof Kate Le Roux (15%).

The survey asked respondents to note their biggest takeaway from the symposium. Responses to this question were varied, however the two most commonly cited lessons include the need to embrace technologies and innovative solutions that are available for teaching and learning, and the value of the academic community in terms of sharing common experiences and challenges (depicted in the word cloud in Figure 8).

Figure 8. Word cloud of most commonly used words to answer the question: 'What is your biggest takeaway from the symposium?'

The majority of respondents (75%) said that they intend to apply this lesson to their future planning. Most of these respondents said that they will do so by exploring and implementing the technologies presented throughout the symposium. Others mentioned increasing accessibility to disadvantaged students, collaborating with colleagues from other institutions, using tutors more widely, and using more formative assessments.

Lastly, the survey asked whether anything was missing from the symposium. Some suggestions from the respondents were:

- Greater engagement between the presenters and the audience, and more time for Q&A;
- Topics relating to the specific ability of teachers and lecturers to improve students' performance. One respondent suggested inviting "*accomplished mathematicians who excel in teaching*";
- Additional ideas on online mathematics assessment;
- Statistical methods used to analyse data; and
- Inviting people "*beyond the Western Cape*", as well as engaging university management at other levels to increase the ability to implement changes.

Overall, the symposium appeared to be well-received and a valuable offering from the CEA team. Some respondents closed off the survey by thanking the team for an interesting and effective event.