

Fostering Belonging: The Impact of a Wise Intervention on Diverse Engineering Students

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Abstract— This study investigates the impact of a scalable, online intervention, that includes sense of belonging and growth mindset activities, on first-year engineering students at a South African research-intensive institution, focusing on those from historically underrepresented groups, including first-generation students and those who come from a less advantaged socioeconomic status (SES) background. The intervention, based on the difference-education approach, aims to foster a sense of belonging, improve academic performance, and promote equity. Participants engaged in activities such as watching videos of diverse senior students sharing their experiences, completing reflections, and surveys. Data was collected from first-year engineering students in 2023 and 2024, and included participants' sense of belonging, emotional experiences, and academic performance in a gateway mathematics course. Statistical analyses revealed that all participants felt a sense of belonging, with first-generation and less advantaged SES students reporting significantly higher positive emotions compared to other students ($p < 0.05$). Notably, intervention participants achieved significantly higher final marks in the engineering mathematics module than non-participants ($p < 0.05$). Thematic analysis identified common themes and challenges faced by students from different backgrounds. The study also explored the synergistic effects of combining a sense of belonging intervention with a growth mindset intervention, revealing promising results for student retention and success. This research contributes to literature emphasizing the effectiveness of wise social belonging interventions in improving university performance and reducing achievement gaps in engineering education. The findings underscore the importance of addressing social belonging to promote diversity, equity, and inclusion in higher education and provide valuable insights for educators and administrators seeking to create more inclusive learning environments.

Keywords— *belonging intervention, achievement gap, underrepresented students, academic performance, scalable intervention*

I. INTRODUCTION

The academic achievement gap between first and second-generation students, as well as between students from disadvantaged and privileged backgrounds, is a well-documented issue in higher education [1, 2], particularly in the South African context. In an effort to address this disparity, the engineering faculty at a research-intensive university in South Africa introduced a series of weekly lectures in the first semester of 2023 for all first year engineering students that address a range of themes, including social belonging and the

development of self-efficacy. These lectures aimed to improve student success by implementing evidence-based interventions that have been shown to close the academic achievement gap [3, 4, 5].

Two of the interventions that formed part of this lecture series were selected for this analysis in this study. Firstly, a difference-education based approach that focused on fostering a sense of belonging was implemented, using the Making Differences Count (MDC) intervention developed by Stephens *et al.* [1, 5]. Secondly, a growth mindset (GM) intervention was implemented, based on the mindset theory as developed by Carol Dweck [6]. Research suggests that combining a sense of belonging intervention, such as the MDC activity, with a growth mindset intervention may yield even greater impacts [7, 8].

The main goals of this project were to explore how first-year engineering students experienced the MDC and/or GM interventions, and to measure its potential impact on academic performance in a traditionally challenging first-year module, Engineering Mathematics 115. In particular, we used statistical analysis to correlate the relationship between students' socioeconomic status (SES) and first- or continuing-generation status (Gen) to the benefit they derived from the interventions. Based on previous research [1, 2], we hypothesized that first-generation students with a less advantaged socioeconomic status would benefit the most from the interventions. We also hypothesized that students who completed the intervention would outperform those who did not, with a more pronounced effect for first-generation students and those with less advantaged socioeconomic status [7, 8].

While social belonging interventions are applicable across all fields of study, this study aims in particular to contribute to the limited research on the combined effects of these interventions within the context of engineering education in the Global South context. In the future, we plan to investigate the impact of the self-affirmation of values intervention, which has also been shown to contribute to closing the academic achievement gap [9].

II. CONCEPTUAL FRAMING AND METHODOLOGY

Wellbeing in professional education programmes has received a great deal of attention since the Covid-19 pandemic and is particularly challenging in resource-constrained, highly inequitable societies [10]. Research in engineering education indicates that psychosocial attributes have increasingly been

foregrounded as necessary conditions for effective, equipped, problem-solving graduates with higher degrees of self-efficacy [11]. Key to developing self-efficacy are structured socio-culturally mediated reflective practice opportunities. Sense of belonging and growth mindset interventions have been shown to benefit students, especially those who are struggling to adjust during the transition to university [1-9]. The following sections detail the range of interventions implemented to address student belonging and wellbeing.

A. Context for research project

This study involved two cohorts of first-year engineering students, the 2023 and 2024 intakes, at a research-intensive university in South Africa. The first-year modules are offered as a common programme for the various engineering disciplines at this university. The 2023 first-year engineering cohort consisted of 800+ students, while the 2024 cohort consisted of 1000+ students. The 2023 and 2024 cohorts were tasked with completing the MDC and GM interventions as online activities over the first weeks of the first semester. In 2023, these activities followed after lectures that introduced the sense of belonging and mindset theories in class. In 2024, the sense of belonging MDC intervention ran as part of the welcoming week activities, while the GM intervention was again part of the first-year engineering lecture series. This enhancement in the implementation process for 2024 allowed for a more representative analysis of the intervention's impact on the entire cohort from the outset of the academic year.

All first-year students were required to complete the activities as part of their studies; however, not all of them did participate. The MDC activity was completed by 403 students in 2023, of which 357 students completed the activity during the semester and the rest (46) after. In 2024, 657 students completed the MDC activity during the semester.

B. Socioeconomic status Scoring System

Socioeconomic status (SES) scores, ranging from 0 to 10, were calculated based on factors such as the student's generation status (Gen), the high school they attended, and their family's financial status. A higher SES score indicates a more disadvantaged background, while a lower SES score indicates a more advantaged background. In this study, we differentiate between students from disadvantaged backgrounds (SES4+) and those from more advantaged backgrounds (SES3-). Additionally, first-generation (Gen1) students are defined as students whose parents or guardians did not complete a university degree, whereas continuing-generation (Gen2+) students are those whose parents or guardians hold a university degree. It should be noted that there is typically overlap between the lower socio-economic status and first-generation status student groups.

C. The Sense of Belonging MDC Intervention

The MDC sense of belonging intervention is a brief, scalable online intervention designed to foster a sense of belonging and inclusivity among first-year engineering students at the university. It can be considered as belonging to a family of wise interventions [5]. The intervention is based on the difference-education methodology proposed by Nicole Stephens [1, 12]. Difference-education aims to recognize and validate students' diverse backgrounds and experiences, promoting a more inclusive learning environment.

The intervention consists of three main components: engaging with senior students' stories through reading and/or

watching videos, a reflective writing activity, and a survey assessing the impact of the intervention on students' perceptions, emotions, sense of belonging, appreciation of diversity, and attitudes towards seeking support.

First-year students are presented with five stories from senior students who share their diverse experiences, challenges, and personal growth during their transition to university life. These stories are designed to convey lessons and insights about navigating the university experience successfully. The stories emphasize that students from different backgrounds can find their own path to success and that seeking support is a normal part of the learning process.

Students have the option to either read the stories or watch videos of the same stories, depending on their preferred learning style. This flexibility fosters a student-centred learning approach.

After engaging with the senior students' stories, first-year students participate in a reflective writing activity. They are asked to consider how their own experiences relate to the stories they have just read or watched, and to identify three ways in which the lessons shared in the stories could help them navigate their own journey at university. Additionally, students are prompted to share three pieces of advice they would give to future incoming students based on the lessons conveyed in the stories.

Following the reflective writing activity, students complete a survey (referred to later as the MDC Survey) assessing the impact of the intervention on various aspects of their university experience. The survey includes questions on:

1. Perceptions of the stories: Students rate the usefulness, enjoyment, relatability, and impact of the stories on their understanding of university life.
2. Emotional impact: Students indicate the extent to which they experienced positive emotions (e.g., empowerment, reassurance, motivation) and negative emotions (e.g., overwhelm, stress, anxiety) after engaging with the stories.
3. Sense of belonging: Students rate their anticipated sense of belonging within the academic and social communities at Stellenbosch University.
4. Appreciation of diversity: Students assess the university's efforts to accommodate diverse backgrounds and perspectives and the importance of having multiple viewpoints on campus.
5. Attitudes towards seeking support: Students indicate their agreement with statements about the normalcy and benefits of seeking help, advice, and mentorship.

The intervention website can be consulted for more detailed information about the MDC [13].

D. The Growth Mindset (GM) Intervention

The GM intervention, based on the work of Carol Dweck [6], aimed to help students understand the difference between fixed and growth mindsets and encourage them to cultivate a growth mindset. The one-hour lecture session focused on the core concepts of mindset theory. Students learned that a fixed mindset is characterized by the belief that personal qualities and abilities are unchangeable, while a growth mindset is based on the belief that these qualities can be developed through effort and experience [6]. The session emphasized the

importance of a growth mindset in navigating the challenges of university life, particularly after the mid-semester assessment period, which can be a stressful time for many students.

To reinforce the concepts presented in the lecture, students were asked to complete two online activities. The first was James Anderson's Growth Mindset Continuum self-assessment [14], which helps individuals identify where they lie on the continuum between fixed and growth mindsets across various domains, such as world view, challenges, effort, and feedback. The second activity was a reflective writing exercise called "20 Guidelines to Developing a Growth Mindset," which prompts students to consider how they can apply growth mindset principles in their lives.

By engaging with these activities, students had the opportunity to deepen their understanding of growth mindset theory and to start developing strategies for cultivating a growth mindset in their academic and personal lives. Research has shown that interventions promoting a growth mindset can lead to improved academic performance, particularly for students facing challenges or setbacks [15].

E. Data Analysis

After the interventions, participant responses were matched with the SES and Gen information that was extracted from the university's student information system. The resulting datasets were statistically analysed using Microsoft Excel and STATISTICA software. To facilitate data exploration and visualization, a Microsoft Power BI application was developed. This application enables quick comparisons of results across different years and faculties and for various subgroups.

Thematic analysis of students' written reflections was performed using Claude.ai, an artificial intelligence-based language model. The process involved carefully examining the responses and identifying common patterns or themes [16]. The data was iteratively reviewed to refine and consolidate the themes until a clear and coherent set of themes emerged. This approach allowed for a deeper understanding of the students' experiences and the impact of the intervention on their sense of belonging, appreciation of diversity, and attitudes towards seeking support.

F. Combined Intervention Analysis

To explore the potential synergistic effects of combining the MDC and GM interventions, the study also investigated the retention rates of students who participated in both interventions. Retention rate was defined as the percentage of students who were still enrolled at the university in the year following the intervention. The hypothesis was that students who participated in both the MDC and GM interventions would have higher retention rates than those who did not participate in any intervention or only participated in the MDC intervention. This analysis aimed to contribute to the limited research on the combined effects of these interventions within the context of engineering education studies.

III. RESULTS

A. Thematic Analysis on Students' Reflective Writing

Through a series of thematic analyses, we have explored the experiences, lessons learned, and advice shared by students from various backgrounds as they navigate their transition to university. By examining the perspectives of

students from advantaged (SES3-) and disadvantaged (SES4+) backgrounds, as well as first-generation (Gen1) and continuing-generation students (Gen2+), we have identified key themes that provide valuable insights into the unique challenges and common threads that unite these diverse groups in their journey through higher education.

1) Themes among SES3- and SES4+ Students

Students from more advantaged backgrounds (SES3-) emphasized themes of seeking support, embracing new experiences, focusing on personal growth, and maintaining a positive mindset. They recognized the importance of balancing academic and social life, developing resilience, and managing family expectations, suggesting a strong foundation of support and a focus on personal development.

In contrast, students from less advantaged backgrounds (SES4+) highlighted themes of overcoming financial obstacles, embracing diversity, developing independence, and building resilience. They placed a greater emphasis on seeking academic support, forming a strong support system, and adapting to a new environment, reflecting the additional barriers and unique perspectives they bring to their university experience.

Despite these differences, both SES3- and SES4+ students acknowledged the importance of seeking help, adapting to a new environment, developing resilience, and balancing their academic and personal lives, underscoring the universal challenges that all students face during their transition to university.

2) Themes among Gen1 and Gen2+ Students

For Gen1 students, prominent themes included seeking help and support, persevering through challenges, and embracing change and adaptation. They emphasized the significance of asking questions, reaching out to lecturers and peers, and utilizing university resources to navigate the unfamiliar terrain of higher education. Additionally, they stressed the value of hard work, determination, and making the most of opportunities, while also balancing academic responsibilities with social and family life.

Gen2+ students, on the other hand, focused on themes such as embracing new experiences, building relationships and networks, and prioritizing self-care and well-being. Gen2+ typically have a greater understanding of the university environment and benefit from the experience of their parents; they emphasized stepping out of their comfort zones, forging meaningful connections with diverse individuals, and maintaining a healthy work-life balance. They also highlighted the role of a positive attitude and the value of seeking help when needed, drawing upon the support of family members who had navigated the university experience before them.

Common themes among both Gen1 and Gen2+ students included the importance of seeking support, balancing academic and personal life, and communicating with family and friends. Both groups acknowledged the transformative nature of the university experience and the need to adapt to new challenges and expectations.

3) Similarities between Gen1 and SES4+ Students, and Gen2+ and SES3- Students

Upon closer examination, we found notable similarities between Gen1 and SES4+ students, as well as between Gen2+ and SES3- students. Gen1 and SES4+ students often shared

themes of overcoming obstacles, developing resilience, and seeking academic support.

In contrast, Gen2+ and SES3- students tended to share themes of embracing new experiences, focusing on personal growth, and maintaining a positive mindset.

Both groups emphasized the importance of hard work, determination, and making the most of opportunities, while also navigating the challenges of adapting to a new environment and balancing multiple responsibilities. Both groups recognized the importance of building relationships, stepping out of their comfort zones, and drawing upon the support of family members who had prior experience with higher education. They also emphasized the value of self-care, time management, and maintaining a healthy work-life balance.

These similarities suggest that while students from different backgrounds face unique challenges, there are common threads that unite them based on their shared experiences and perspectives. By recognizing these similarities, universities can develop support systems and interventions that potentially address the needs of multiple student groups simultaneously, fostering a more inclusive and equitable learning environment.

B. The MDC Survey

This study examined the experiences of various student subgroups participating in the intervention via the MDC Survey, focusing on six key dimensions: (1) positive perceptions, (2) felt positive emotions, (3) felt negative emotions, (4) sense of belonging, (5) university appreciating and accommodating differences, and (6) seeking support and asking for advice. To determine the significance of differences between subgroups, independent sample t-tests were conducted using STATISICA software. By analysing these differences, we can identify areas where targeted support may be necessary to ensure a more equitable and inclusive learning environment. The results for 2024 and 2023 are given below, highlighting in which area significant differences were evident in certain SES and Gen subgroups.

1) Results of the 2024 MDC Survey

The survey, which included 13 questions on students' perceptions of the MDC intervention, revealed an overall positive perception score of 4.41 out of 7 for the entire 2024 cohort.

The *positive emotions* section of the survey, consisting of 14 questions, yielded an overall score of 4.68 out of 7 for the entire cohort (n = 657). These results suggest that the overall perceptions of the MDC intervention was positive and that it had a generally positive emotional impact on the participants.

However, a more in-depth analysis of the subgroups revealed some noteworthy patterns on both the positive perceptions and positive emotions sections: Gen1 students (n = 250) reported significantly higher scores than Gen2+ students (n = 368) in both positive perceptions ($p < 0.001$) and felt positive emotions ($p < 0.001$), highlighting the importance of supporting first-generation students who may face additional challenges in navigating the university environment [17]. The generation status of 39 students was unknown.

Similarly, students from more disadvantaged socioeconomic backgrounds (SES4+, n = 134) reported significantly higher scores than those from less disadvantaged

socioeconomic backgrounds (SES3-, n = 523) in positive perceptions ($p < 0.001$) and felt positive emotions ($p < 0.001$). This finding suggests that students from more disadvantaged socioeconomic backgrounds benefit more from additional support that fosters a sense of belonging and instils positive emotions.

The *negative emotions* section of the survey, which included 6 questions, revealed an overall score of 2.49 out of 7 for the entire cohort, indicating that the MDC was generally well-received, with no significant differences found between the generational and socioeconomic status groups.

The *sense of belonging* section, comprising 5 questions, yielded an overall score of 5.48 out of 7 for the entire cohort, suggesting that the intervention was successful in promoting a sense of belonging among the participants.

The *appreciating and accommodating differences* section of the survey, which included 5 questions, revealed an overall score of 6.04 out of 7 for the entire cohort. This high score indicates that the intervention effectively promoted a sense of inclusivity and diversity among the participants. Students generally agreed that there are different ways to succeed at this university (6.23 out of 7) and that it is important to have multiple perspectives on campus (6.23 out of 7).

The *seeking support and asking for advice* section, consisting of 5 questions, yielded an overall score of 6.06 out of 7 for the entire cohort. This high score suggests that the intervention successfully promoted positive attitudes towards help-seeking and mentorship. Students generally agreed that it is normal to ask for help outside of class (6.23 out of 7) and that mentors play an important role in helping them succeed academically (6.26 out of 7) and plan for their future (5.91 out of 7).

No significant differences were found between the generational and socioeconomic status groups in the felt negative emotions, sense of social belonging, university appreciating and accommodating differences, and seeking support & asking for advice dimensions of the survey.

2) Results of the 2023 MDC Survey

Very similar results were obtained from the analysis on the 2023 cohort.

The analysis revealed significant differences in the experiences of Gen1 (n = 95) and Gen2+ (n = 262) students. Gen1 students reported higher levels of positive perceptions ($p=0.00089$) and positive emotions ($p=0.00648$) compared to Gen2+ students. This finding suggests that the MDC intervention may have a more pronounced positive impact on Gen1 students, who often face unique challenges in navigating the university environment. Previous research has highlighted the importance of targeted support for Gen1 students, as they may lack the social capital and familial guidance that second-generation or higher students often possess [1].

Significant differences were found between SES4+ (n = 29) and SES3- (n = 328) students in positive perceptions ($p=0.00028$), positive emotions ($p=0.02357$), and seeking support and asking for advice ($p=0.01498$). In all three dimensions, SES4+ students reported higher scores compared to their SES3- peers. These findings again suggest that the MDC intervention may be particularly beneficial for students from more disadvantaged backgrounds, empowering them to seek support, experience positive emotions, and develop positive perceptions. The intervention's emphasis on seeking

support and asking for advice aligns with research highlighting the importance of social capital and support networks for students from disadvantaged backgrounds [2].

3) Key Takeaway from the Survey Results

The MDC social belonging intervention therefore seems to have the potential to foster a more inclusive and supportive environment for these engineering students. However, the experiences of student SES and Gen subgroups vary, highlighting the need for targeted interventions and support systems. By addressing the unique needs of Gen1 students and those from lower socioeconomic backgrounds, the university can work towards creating a more equitable and diverse engineering community that empowers all students to succeed. The MDC intervention appears to be a promising approach in addressing these disparities and promoting a stronger sense of belonging among first-generation, less advantaged socioeconomic status engineering students.

C. The Impact of the MDC on Pass Rates in Engineering Mathematics 115

The study used a two-proportion z-test ($\alpha=0.05$) to compare the pass rates of students who completed the MDC intervention and those who did not, for the entire Cohort 2023 and four subgroups: Gen1, Gen2+, SES3-, and SES4+.

Significant differences in pass rate (a final mark of 50% or above) were found between MDC participants and non-participants for the entire cohort (81.39% vs. 69.33%, $z = 4.0311$, $p < 0.0001$), Gen1 (74.11% vs. 58.28%, $z = 2.7333$, $p = 0.0063$), Gen2+ (84.19% vs. 75.33%, $z = 2.6765$, $p = 0.0074$), and SES3- (83.61% vs. 73.71%, $z = 3.2743$, $p=0.0011$) subgroups. However, no significant difference was found for the SES4+ subgroup.

These findings suggest that the MDC intervention is associated with higher pass rates in Engineering Mathematics 115 for the entire cohort and several subgroups, indicating its potential effectiveness in promoting academic success and helping students overcome background-related challenges.

The lack of a significant difference for the SES4+ subgroup may be due to the smaller sample size ($n = 37$) or other factors not accounted for in this study. Further research is needed to explore the reasons behind this finding and identify strategies for improving the intervention's effectiveness for this subgroup.

These results highlight the intervention's potential to support student success and help close the achievement gap. Additional research is warranted to investigate the long-term impact of the intervention on student outcomes and identify best practices for implementing similar interventions in other educational contexts.

D. The Impact of the MDC on Academic Performance in Engineering Mathematics 115

The study compared the final marks in Engineering Mathematics 115 for students who completed the MDC intervention and those who did not, across four groups: Gen1, Gen2, SES3-, and SES4+. A two-sample t-test assuming equal variances ($\alpha=0.05$) was used to determine statistically significant differences in academic performance between MDC participants and non-participants within each group.

Results showed that MDC participants outperformed non-participants consistently across all groups. The differences were statistically significant for Gen1 (53.34 vs. 43.91, $p <$

0.0001), Gen2 (58.89 vs. 52.04, $p < 0.0001$), SES3- (58.28 vs. 51.33, $p < 0.0001$), and SES4+ (48.16 vs. 40.74, $p = 0.03376$).

These findings suggest that participation in the MDC intervention is correlated to improved academic performance and thus may help to close the achievement gap across various student groups, regardless of their generational or socioeconomic background.

One possible explanation for the observed differences could be related to self-selection bias [17, 18]. While the results indicated that participation in the MDC intervention is correlated to improved performance, this may be a knock-on effect related to the role of conscientiousness, where students who chose to participate in the MDC intervention may be inherently more conscientious. However, further research is needed to explore this hypothesis and determine if the intervention itself fosters the development of conscientiousness or other beneficial traits.

E. The Impact of the MDC and GM Interventions on Student Retention Rates

Retention rate is calculated as the percentage of first-time entry students in 2023 who were retained within the university in 2024, not necessarily within an engineering programme. A small proportion of these students may have changed their course of study outside of engineering.

1) Retention and Participation per Type of Intervention

Fig. 1 and Fig. 2 present first-year participation rates and retention rates, respectively, for various student groups based on their involvement in the MDC, GM, and combined MDC and GM interventions. Key observations include:

1. Students who participated in both MDC and GM had the highest retention rates (93.10% to 100%).
2. MDC participants had higher retention rates than non-participants across all groups.
3. Gen1 students had lower retention rates than Gen2+ students.
4. SES4+ students had significantly lower retention rates than SES3- students.
5. Participation rates in MDC were higher among Gen2+ and SES3- students.
6. Participation rates in combined MDC and GM were relatively low (3.60% to 23.48%).
7. Strong positive correlations between retention rates and participation rates in MDC ($r = 0.995$) and both MDC & GM ($r = 0.996$) suggest a potential link between conscientiousness and participation.

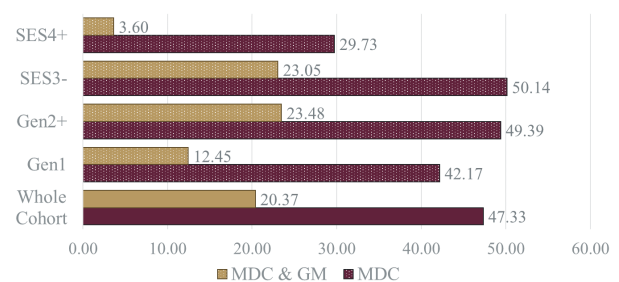


Fig. 1 Participation rates per subgroup and type of intervention

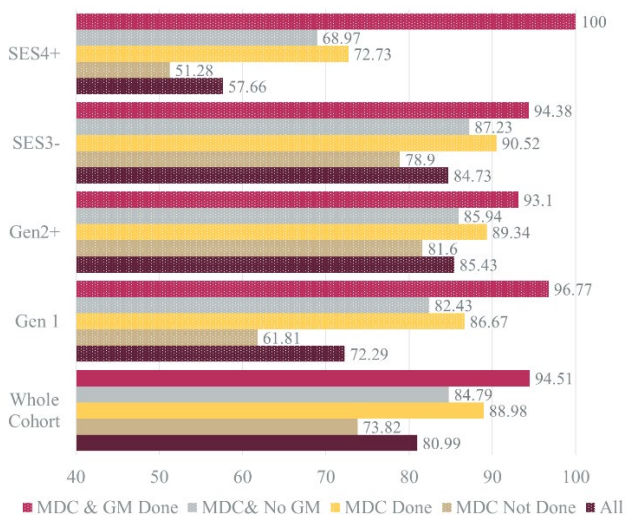


Fig.2 Retention rates per subgroup and type of intervention.

Fig. 1 highlights the positive impact of MDC and GM interventions on student retention, particularly when combined. However, it also reveals disparities based on generational status and socioeconomic background, emphasizing the need for targeted support and efforts to increase participation among underrepresented groups. The potential link between conscientiousness and participation in these interventions should be further explored to better understand factors contributing to student success.

Future investigations could compare retention rates to pre-Covid data for matched student groups or use a control group to eliminate self-selection bias, while addressing potential ethical concerns.

2) Results from a Statistical Analysis of Retention Rates

A two-proportion z-test ($\alpha=0.05$) was used to compare retention rates of students who completed the MDC and GM interventions and those who did not, for the entire Cohort 2023 and subgroups: Gen1, Gen2+, SES3-, and SES4+.

For the entire cohort, the retention rate was significantly higher for MDC Done students (88.98%) compared to MDC Not Done students (73.82%) ($z = 5.5033$, $p < 0.0001$). Similarly, the retention rate for MDC & GM Done students (94.51%) was significantly higher than that of MDC GM & No GM students (84.79%) ($z = 3.0146$, $p=0.0026$).

Significant differences were also found in the following subgroups:

1. Gen1: MDC Done (86.67%) vs. MDC Not Done (61.81%) ($z=4.3809$, $p<0.0001$)
2. Gen2+: MDC Done (89.34%) vs. MDC Not Done (81.60%) ($z=2.4583$, $p=0.0140$)
3. SES3-: MDC Done (90.52%) vs. MDC Not Done (78.90%) ($z=4.2614$, $p<0.0001$)
4. SES3- MDC & GM Done (94.38%) vs. MDC & No GM (87.23%) ($z=2.2896$, $p=0.0220$)

The SES4+ MDC & GM Done group had a 100% retention rate ($n = 4$), but the small sample size limits meaningful conclusions.

This study provides evidence that the MDC intervention and the combination of MDC and GM interventions are

associated with significantly higher retention rates compared to non-participation, emphasizing the importance of targeted interventions to support student retention and success, especially for disadvantaged students.

Further research is needed to explore the long-term impact and mechanisms behind the effectiveness of these interventions, and to identify best practices for implementation in other educational contexts.

IV. DISCUSSION

F. General

The findings of this study highlight the potential of the MDC and GM interventions in promoting student success, retention, and a sense of belonging among engineering students at Stellenbosch University. Importantly, these interventions may serve as a contributing solution to the well-documented academic achievement gap [1, 8]. The results demonstrate that these interventions are associated with improved academic performance, higher pass rates, and increased retention rates across various student subgroups, including first-generation students, continuing-generation students, and those from different socioeconomic backgrounds.

The thematic analysis of student experiences and perceptions provides valuable insights into the unique challenges faced by students from disadvantaged backgrounds and first-generation students, as well as the common threads that unite all students in their transition to university. These findings underscore the importance of developing targeted interventions and support systems that address the specific needs of these student groups while fostering a sense of belonging and inclusivity for all. An area for further research would be to explore a deeper, qualitative study on feedback from first-year students in future years.

The positive impact of the MDC intervention on academic performance and pass rates, as well as first-year retention rates, suggests that promoting a sense of social belonging can have tangible benefits for student success. This aligns with previous research highlighting the importance of social belonging in academic settings [3, 5] and the potential of belonging interventions to close achievement gaps [5, 8]. However, it is important to note that the improved performance of students who participated in the MDC intervention may be driven by either an enhanced sense of belonging or higher levels of conscientiousness, or a combination of both.

While the current study did not directly measure conscientiousness, it is possible that students who chose to participate in the interventions may be more conscientious, contributing to their higher levels of academic achievement. Previous research has established conscientiousness as a strong predictor of academic performance [21, 22]. Conscientious individuals are often described as being responsible, organized, and goal-oriented [23]. They tend to be more likely to engage in behaviours that promote their personal growth and success, such as participating in academic support programs or seeking help when needed [21].

Regardless of the specific mechanism driving the improved performance, the fact remains that students who participate in the MDC intervention perform better academically. This presents an opportunity to explore

innovative ways to enhance both sense of belonging and conscientiousness among students.

One potential approach could be to integrate elements of the MDC intervention with strategies that promote the development of conscientiousness, such as goal-setting, time management, and self-regulation skills [23]. By providing students with a comprehensive support system that addresses both social belonging and conscientiousness, engineering programs may be able to maximize the impact of these interventions on student success and help close the academic achievement gap.

Moreover, the finding that the combination of the MDC and GM interventions is associated with significantly higher retention rates compared to the MDC intervention alone or no intervention is particularly promising. This suggests that addressing both social belonging and growth mindset may have a synergistic effect on student retention and success. The results support the idea that fostering a growth mindset, which emphasizes the malleability of intelligence and the value of effort and perseverance [15], can complement the benefits of social belonging interventions.

It is worth noting that the impact of the MDC intervention on other groups, such as gender, race, and students with different grade 12 results, was also investigated. These analyses, including thematic analyses, impact on performance and pass rates in Engineering Mathematics 115, and retention rates, are available on a supporting website [20]. These additional analyses provide a more comprehensive understanding of the intervention's effectiveness across diverse student populations.

G. Strengths of the Study

This study has several notable strengths that contribute to its relevance and potential impact in the field of engineering education. First, it addresses the critical issue of fostering a sense of belonging and promoting equity for historically underrepresented groups, which is crucial for increasing diversity, equity, and inclusion in STEM fields. Second, the online social belonging intervention implemented in this study is designed to be scalable, allowing for easy delivery to a large number of students without requiring extensive resources. Third, the study employs a robust mixed-methods approach, combining quantitative data (MDC Surveys and academic performance) with qualitative data (thematic analysis of written reflections), allowing for a comprehensive understanding of students' experiences and the intervention's impact. Fourth, the longitudinal design, which implements the intervention across two academic years (2023 and 2024) and collects data at multiple time points, captures a long-term perspective on the intervention's impact, strengthening the validity of the findings. Finally, the study is grounded in the existing literature on social belonging and difference-education interventions, providing a strong theoretical foundation and positioning the findings within the broader context of evidence-based practices in higher education. The practical implications of the study's findings offer valuable insights and strategies for educators and administrators seeking to create more inclusive learning environments.

H. Limitations of the Study

Despite its strengths, this study has several limitations that should be acknowledged. First, the voluntary nature of participation in the intervention may lead to self-selection bias, as students who chose to participate may have different

characteristics, motivations, or prior experiences compared to those who did not. Second, the study only examines the intervention's impact on performance in a single course, which may not fully represent students' academic performance throughout their entire engineering program. Third, there may be confounding factors not fully accounted for in the study, such as prior academic preparation, family support, or institutional climate, which could influence students' sense of belonging, emotional experiences, and academic performance. Fourth, the quantitative analysis approach that was taken in this study does not provide the depth and richness of a more thorough qualitative analysis that could combine thematic analysis of students' written reflections with in-depth interviews or focus groups. Lastly, the study was conducted at a single institution, and the effectiveness of the intervention may vary in different institutional contexts or with different student populations.

I. Suggestions for Future Research

Building upon the findings and limitations of this study, several avenues for future research can be explored to further advance our understanding of social belonging interventions and their impact on diverse student populations in engineering education. First, future research could examine the intersectionality of students' identities, exploring the experiences of those who belong to multiple underrepresented groups and how different aspects of identity interact to shape their sense of belonging and academic outcomes. Second, the perspectives and roles of faculty and staff in creating inclusive learning environments and supporting diverse students could be investigated, including studies on faculty members' attitudes and practices related to fostering belonging and the impact of faculty and staff diversity on students' sense of belonging and academic success. Third, future studies could examine the effectiveness of social belonging interventions across different institutional and disciplinary contexts to identify factors that influence the success of these interventions in various settings. Fourth, delving deeper into the psychological mechanisms underlying the effectiveness of social belonging interventions, such as changes in students' self-efficacy, motivation, or identity development, could provide valuable insights. Finally, longitudinal studies could investigate the long-term impact of social belonging interventions on students' academic and career trajectories, such as their persistence in engineering majors, graduation rates, or post-graduation employment outcomes.

J. Recommendations

Based on the findings of this study, several practical recommendations can be made to support student success and retention in engineering programs:

1. Expand the implementation of the MDC and GM interventions to reach a larger proportion of the student population, particularly targeting first-generation students and those from disadvantaged backgrounds.
2. Geoffrey Cohen from Stanford University emphasizes the importance of interventions being targeted, tailored, and timely to maximize their effectiveness [3, 24]. In line with these recommendations, we have refined our approach by moving the MDC intervention to the welcoming program, where its timing is more appropriate and its impact potentially greater. An important

recommendation is therefore to continuously evaluate existing interventions against these criteria to ensure their success in supporting students, particularly those from underrepresented groups.

3. Find ways to enhance participation rates in the lectures, which already include GM, self-affirmation of values, and resilience training, to ensure that more students can directly benefit from these interventions.
4. Develop additional support programs and resources that address the specific challenges and needs identified through the thematic analysis, such as financial support, academic advising, and mentorship opportunities.
5. Continue to foster a culture of inclusivity and diversity within the engineering faculty, promoting the value of multiple perspectives and experiences in the learning environment.
6. Explore innovative ways to enhance both sense of belonging and conscientiousness among students, such as integrating elements of the MDC intervention with strategies that promote the development of conscientiousness-related skills.
7. Consider incorporating the OCEAN (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) Big 5 personality framework into the curriculum to cultivate awareness of personality traits and their connection to success and well-being. Provide students with opportunities to develop and enhance their conscientiousness [25], which has been linked to academic success and positive life outcomes [23].
8. Use non-participation in first-year interventions (such as the MDC and GM) as an early alert system to identify and support students facing additional barriers to success, particularly first-generation and disadvantaged students. Offering tailored resources and continuously refining the system based on data can help close achievement gaps and foster a more inclusive learning environment.
9. Conduct further research to investigate the specific mechanisms driving the improved performance of students who participate in the MDC intervention, as well as to identify best practices for implementing similar interventions in other educational contexts.

IV. CONCLUSIONS

This study provides compelling evidence for the effectiveness of the MDC and GM interventions in promoting student success, retention, and a sense of belonging among engineering students at Stellenbosch University. The findings highlight the importance of addressing the unique challenges faced by students from diverse backgrounds and emphasize the potential of combining social belonging and growth mindset interventions to support student outcomes and help close the academic achievement gap.

While the specific mechanisms driving the improved performance of students who participate in the MDC intervention may be either an enhanced sense of belonging or higher levels of conscientiousness, or a combination of both, the fact remains that these students perform better

academically. This presents an opportunity to explore innovative ways to enhance both sense of belonging and conscientiousness among students, potentially maximizing the impact of these interventions on student success.

By implementing these interventions more broadly, developing additional support systems informed by the thematic analysis, investigating strategies to promote conscientiousness alongside social belonging, and considering the integration of the OCEAN Big 5 personality framework into the curriculum, the engineering faculty can create a more inclusive and equitable learning environment that empowers all students to reach their full potential.

Research will continue to replicate these results with future cohorts and measure the long-term impact on throughput rates. Additionally, the impact of the GM, self-affirmation of values, and resilience interventions will be investigated separately to gain a more comprehensive understanding of their individual contributions to student success.

Further research into the long-term impact of these interventions and the interplay of social belonging and conscientiousness in student success will contribute to the ongoing effort to close achievement gaps and ensure the success of all students in engineering programs.

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