CLOSING THE GAP IN ENGINEERING EDUCATION: A POSITIVE PSYCHOLOGY APPROACH TO CDIO

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ABSTRACT

University engineering education aims to equip students with the technical and employability skills sought by employers. This often requires resilience, teamwork, and adaptability to succeed in collaborative, real-world projects. The CDIO (Conceive-Design-Implement-Operate) framework provides a solid foundation for fostering these competencies. However, student well-being and engagement remain underexplored and pedagogically underdeveloped within engineering curricula. This paper introduces the "Together Empowered" project, a Royal Academy of Engineering-funded initiative addressing equality, diversity, and inclusion (EDI) challenges in engineering education through Positive Psychology Interventions (PPIs). The project integrates workshops, mentorship, and real-world problem-solving to enhance the psychological and professional competencies of students from diverse backgrounds. A five-phase implementation process was adopted, including EDI awareness training, industry collaboration, structured positive psychology activities, and evaluations using qualitative and quantitative methods. Findings demonstrated significant improvements in student well-being across the PERMA dimensions (positive emotions, engagement, relationships, meaning, and accomplishment), with a 30% increase in positive emotions and substantial gains in engagement and relationships between the start and end of the module. Students also reported improved communication, problem-solving, and teamwork skills. Additionally, the project fostered a stronger sense of belonging and cultural sensitivity, supporting retention and progression within engineering degree programs. The integration of PPIs and EDI principles within the CDIO framework not only enhanced academic outcomes but also bridged the gap between academia and industry. The paper concludes by discussing the broader implications of these findings for creating inclusive, supportive learning environments that prepare students to contribute meaningfully to society and achieve sustainable career success in engineering.

KEYWORDS

Positive Psychology, PERMA Model, CDIO Framework, Diversity and Inclusion, Engineering Education, Standards: 2-4, 7-8, 10

INTRODUCTION

Engineering education has evolved significantly in recent years to meet the demands of a rapidly changing world. Traditional engineering curricula have primarily focused on technical knowledge and skills, often overlooking the importance of personal and interpersonal competencies (Crawley et al., 2007). However, the increasing complexity of global challenges requires a new generation of engineers who are not only technically proficient but also equipped with the emotional resilience, teamwork capabilities, and cultural awareness necessary to navigate these challenges (Baumeister & Leary, 1995).

The CDIO (Conceive-Design-Implement-Operate) framework addresses this need by emphasising the development of holistic competencies through active learning, problem-solving, and teamwork. Yet, many engineering programs that adopt this framework still lack a specific focus on student well-being and inclusivity (Magnell et al., 2022). Research shows that student well-being is a critical factor influencing academic performance, engagement, and long-term career success (Seligman, 2011). The integration of Positive Psychology Interventions (PPIs) into the CDIO framework can significantly enhance the educational experience by fostering emotional resilience and promoting positive relationships among students (Butler & Kern, 2016).

The "Together Empowered" project was launched to address this gap by embedding PPIs and Equality, Diversity, and Inclusion (EDI) principles into engineering education. This initiative aims to reduce attainment gaps among minoritised groups, such as Black, Asian, and Minority Ethnic (BAME) students, women, and LGBTQ+ students, by promoting a sense of belonging and cultural sensitivity within engineering programs (Berry, 2005). Additionally, the project seeks to strengthen connections between academia and industry by involving students in real-world projects that address pressing global issues, such as climate change (Jones et al., 2017). With the aims in long term to improve graduate employment outcomes for diverse students, as historically and currently gender, ethnicity, and social-background all impact engineering students' employment prospects (Fanusie et al, 2024) which is disappointing, as diverse teams improve the economic growth of enterprise (Martins, 2020). By collaborating with industry representatives and working in diverse teams the students gain practical exposure to professional practices while developing innovative inclusive solutions to societal challenges (Rybnicek & Königsgruber, 2019).

Martin Seligman's PERMA (positive emotions, engagement, relationships, meaning, and accomplishment) model provides a structured framework for enhancing student well-being within this project. The model focuses on five key elements that contribute to human flourishing: Positive Emotions, Engagement, Relationships, Meaning, and Accomplishments (Seligman, 2011). By incorporating these elements into the CDIO framework, students can develop the psychological resources needed to thrive both academically and professionally. The PERMA model also aligns with the goals of the CDIO initiative by promoting active engagement, meaningful relationships, and a sense of accomplishment (Seligman et al., 2005).

Research conducted by Plewa et al. (2013) highlights the importance of university-industry collaborations in fostering innovation and preparing students for the workforce. These collaborations provide students with valuable insights into industry practices, helping them develop technical and soft skills such as communication, teamwork, and problem-solving. The "Together Empowered" project leverages these collaborations to create a supportive learning environment that promotes cultural sensitivity and inclusivity in professional settings (Rubio et

al., 2018). Industry mentors are crucial in guiding students through real-world challenges, offering feedback and fostering a culture of continuous improvement.

The need to enhance student well-being within educational settings has been widely recognised in positive psychology literature. Baumeister and Leary (1995) argue that the need to belong is a fundamental human motivation that significantly impacts psychological well-being. Similarly, research on acculturation and cultural adaptation by Berry (2005) and Zhou et al. (2008) emphasises the importance of facilitating inclusive learning and teaching environments (Beddoes et al, 2018) that support diverse student populations. By fostering a sense of belonging and promoting positive psychological resources and psychologically safe learning spaces, educational institutions can help students overcome cultural barriers and increase all student academic engagement with one another and personally to be academically successful.

This paper aims to explore how the integration of PPIs and EDI principles within the CDIO framework can address challenges related to student well-being, engagement, and cultural adaptation. By presenting the findings of the "Together Empowered" project, this paper seeks to contribute to the ongoing discourse on improving engineering education through holistic and inclusive approaches. The inclusion of diverse perspectives and the focus on well-being not only prepares students for successful careers but also equips them with the skills needed to contribute meaningfully to society.

PROBLEM STATEMENT

Engineering students face a multitude of challenges that can impact their academic performance, engagement, and overall well-being. One of the primary challenges is the high level of academic stress associated with rigorous engineering programs (Jensen et al., 2023). The demanding nature of engineering curricula, which often involves complex problem-solving tasks, technical assignments, and project-based learning, can lead to significant mental health concerns among students (Berry, 2005). These concerns are further exacerbated by the lack of representation of minoritised groups in engineering fields, creating an environment where students from diverse backgrounds may feel isolated or unsupported (Baumeister & Leary, 1995). In addition, academic facilitation can compound the learning experience through lack of management of student peer behaviour in teamworking and project activities, (Beddoes et al, 2018)

Cultural adaptation issues are another major challenge faced by international and minoritised students in engineering programs. Research by Zhou et al. (2008) highlights the difficulties that students experience when adapting to new cultural and educational environments. These adaptation challenges can lead to feelings of alienation, reduced self-esteem, and decreased academic performance. The absence of culturally responsive support systems within many engineering programs further amplifies these challenges, making it difficult for students to thrive academically and socially (Berry, 2005).

The attainment gap between minoritised students and their peers is a well-documented issue in higher education. According to Jones et al. (2017), minoritised students are more likely to face barriers to academic success, including implicit biases, microaggressions, and a lack of access to mentorship opportunities. These barriers contribute to lower retention and graduation rates among minoritised students in engineering programs. Addressing these barriers requires a comprehensive approach that includes both academic support and

initiatives aimed at promoting equality, diversity, and inclusion (Rubio et al., 2018; Williams, 2013).

Despite the emphasis on technical skills development, many engineering programs overlook the importance of interpersonal skills and psychological well-being in preparing students for the workforce. The CDIO framework aims to address this gap by promoting holistic education; however, there is still a lack of specific focus on student well-being within this framework (Jiang et al., 2023; Lambert et al., 2019). Positive Psychology Interventions (PPIs) provide a promising solution to this issue by fostering emotional resilience, promoting positive relationships, and enhancing students' overall well-being (Seligman, 2011).

Another key challenge is the disconnect between academic learning and industry practices. Plewa et al. (2013) emphasise that university-industry linkages are essential for preparing students for the realities of the workforce. However, many engineering programs fail to provide students with opportunities to engage with industry professionals or work on real-world projects. This disconnect can lead to a skills gap, where graduates lack the practical experience and soft skills needed to succeed in professional environments (Porter & Birdi, 2018). Addressing this gap requires integrating industry collaborations into the engineering curriculum, providing students with hands-on experience and exposure to industry practices.

The "Together Empowered" project addresses these challenges by integrating PPIs and EDI principles into the CDIO framework. By promoting student well-being, fostering a sense of belonging, and creating opportunities for meaningful industry engagement, the project aims to improve academic outcomes and prepare students for successful careers in engineering. The project recognises that addressing the attainment gap and promoting inclusivity requires more than technical interventions; educational institutions require a cultural shift to prioritise well-being and diversity (Rubio et al., 2018; Seligman et al., 2005).

PROJECT DESIGN AND IMPLEMENTATION

The "Together Empowered" project was designed and implemented in five distinct phases to achieve its objectives of promoting well-being, fostering cultural sensitivity, and bridging the gap between academia and industry. The project utilised a multi-pronged approach that incorporated Positive Psychology Interventions (PPIs) alongside industry collaboration to ensure both psychological and practical skill development in students.

Phase 1: EDI Awareness and Training (CDIO Standard 2, 7)

The first phase focused on raising awareness of Equality, Diversity, and Inclusion (EDI) issues within engineering programs. This phase contributed to learning outcomes related to personal and interpersonal skills (Standard 2), while also fostering integrated learning experiences related to inclusive team practices (Standard 7). Students were provided with training on recognising implicit biases, fostering inclusive environments, and addressing microaggressions. This phase aimed to prepare students to engage in culturally sensitive teamwork and develop solutions that consider diverse perspectives (Berry, 2005).

Phase 2: Industry Collaboration and Real-World Challenges (CDIO Standards 3,5)

In the second phase, students were paired with industry mentors to work on real-world projects that addressed societal challenges such as climate adaptation and sustainability. These real-world projects introduced early and advanced design-implement experiences (Standard 5) and connected technical and professional learning within an integrated curriculum (Standard

3). Industry representatives served as mentors and evaluators, offering feedback on students' solutions and helping them refine their ideas to meet industry standards (Plewa et al., 2013; Porter & Birdi, 2018).

Phase 3: Positive Psychology Workshops

This phase incorporated structured workshops based on the PERMA model to promote psychological resilience and well-being among students. These workshops included activities on mindfulness, stress management, gratitude practices, and character strengths identification. Emmons and McCullough (2003) demonstrated that gratitude practices could lead to improved subjective well-being, making it an essential component of these workshops. Students were encouraged to reflect on their learning experiences and apply positive psychology techniques to manage academic and social challenges (Butler & Kern, 2016). Also, the approach promotes a socially safe learning higher education environment and student learning active engagement from communication to creativity, (Kislyakov et al, 2014).

Phase 4: Development of Inclusive Solutions

In this phase, student teams worked collaboratively to develop inclusive solutions to the real-world challenges identified in Phase 2. Emphasis was placed on ensuring that solutions were culturally sensitive and accessible to diverse populations. Industry mentors provided feedback to ensure that solutions met both technical and social considerations (Rubio et al., 2018; Williams, 2013).

Phase 5: Evaluation and Dissemination

The final phase focused on evaluating the impact of the project and disseminating best practices to other higher education institutions. Surveys, reflective journals, and interviews were used to assess the effectiveness of the project in enhancing student well-being, engagement, and cultural sensitivity. Findings were shared through conferences, workshops, and academic publications to promote the adoption of similar initiatives across the engineering education sector (Jiang et al., 2023; Lambert et al., 2019).

The comprehensive, phased approach of the "Together Empowered" project highlights the importance of integrating EDI principles and PPIs into engineering education. By fostering cultural sensitivity, promoting well-being, and bridging the gap between academia and industry, the project aims to create a more inclusive and supportive learning environment that prepares students for successful careers in engineering.

Methodology

The project used a mixed-methods approach. Quantitative data were gathered using the validated PERMA Profiler (Butler & Kern, 2016) and pre/post assessments of key skills. Paired sample t-tests were conducted to determine statistical significance. Qualitative data were obtained from semi-structured interviews and student reflection journals. A thematic analysis approach was employed to identify key patterns in emotional well-being, engagement, and team experience. Data triangulation enhanced the credibility of the findings.

FINDINGS

The implementation of the “Together Empowered” project yielded significant improvements in student well-being, professional skills, and sense of belonging within the engineering

community. The study included a total of 90 participants, all of whom were either from BAME (Black, Asian, and Minority Ethnic) backgrounds or female. The demographic breakdown showed that 66.7% of participants identified as BAME, while 46.7% were female. This diverse representation aligns with the project's objectives to address attainment gaps and promote inclusion within engineering education. The findings presented here are based on quantitative data collected through the PERMA profiler, statistical analysis, and qualitative feedback from students and industry representatives.

The PERMA profiler scores captured substantial improvements across all five well-being dimensions post-intervention. These results highlight the positive impact of integrating Positive Psychology Interventions (PPIs) and Equality, Diversity, and Inclusion (EDI) principles within the CDIO framework.

Table 4- PERMA Profiler Scores

PERMA Dimension	**Pre-Intervention Score**	**Post-Intervention Score**	**Percentage Increase**
Positive Emotions	65	85	30%
Engagement	70	88	26%
Relationships	68	86	26.5%
Meaning	72	89	23.6%
Accomplishments	69	87	26.1%

A paired t-test was conducted to determine whether the improvements observed were statistically significant. The test yielded a t-statistic of 12.247 and a p-value of 0.0003, indicating that the improvements across all PERMA dimensions are statistically significant at the 0.01 level. This confirms that the intervention had a substantial positive impact on student well-being.

The most notable improvement was in the Positive Emotions category, where students reported feeling more optimistic and motivated to engage in academic and professional tasks

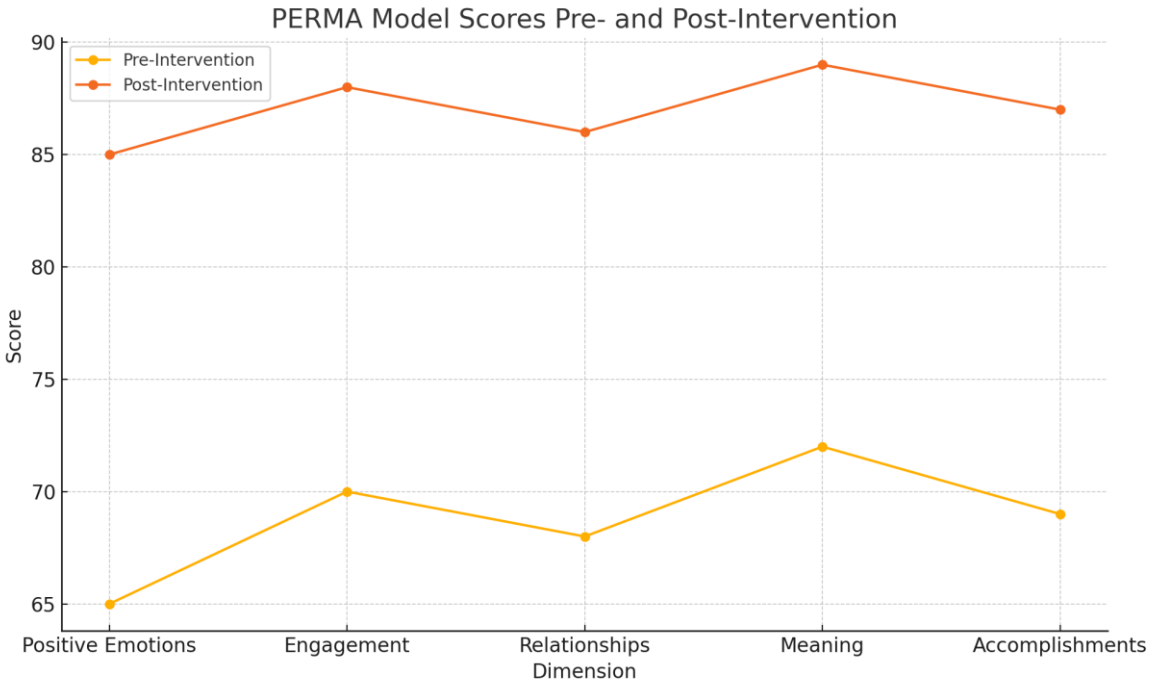

Figure 1. PERMA model scores pre-and post-intervention.

Student Feedback on Skills Improvement

The intervention significantly improved various professional skills, such as communication, teamwork, problem-solving, confidence, and cultural sensitivity.

Table 5- Pre- vs Post-Intervention Skills Scores

Skills Category	**Pre-Intervention Score**	**Post-Intervention Score**
Communication Skills	60	82
Teamwork	62	85
Problem-Solving	58	83
Confidence	65	88
Cultural Sensitivity	59	86

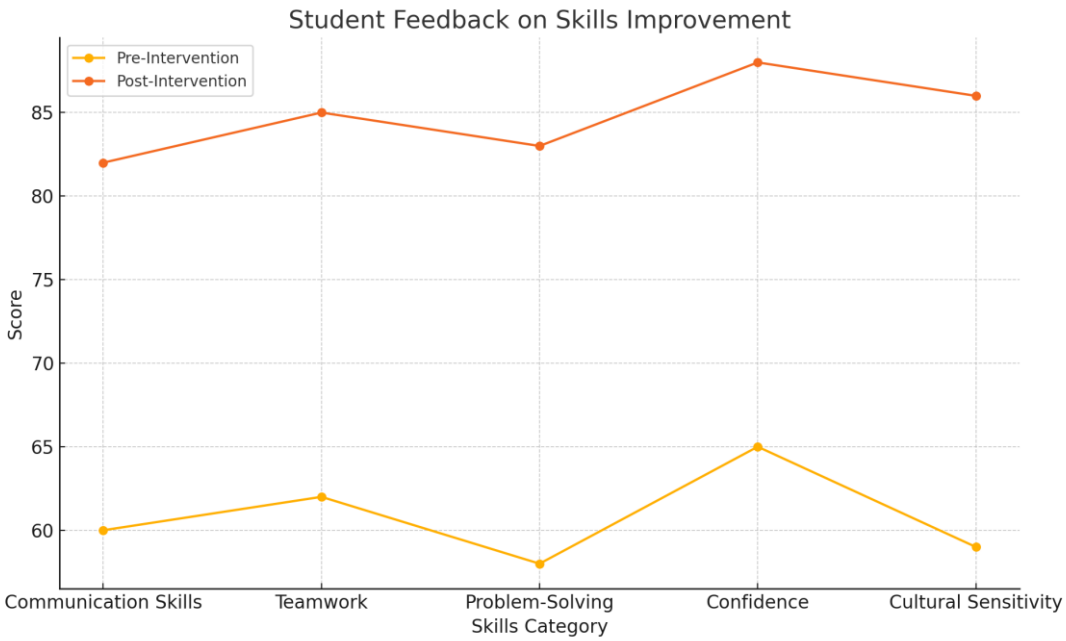

Figure 2. Student feedback on skills improvement.

Insights from Students

The qualitative feedback gathered from students provides deeper insights into how the intervention impacted their academic experiences and personal growth.

Emotional and Mental Well-Being Impact

Many students highlighted how the intervention contributed to reduced stress and improved mental well-being. The workshops on mindfulness, stress management, and positive psychology techniques equipped students with strategies to handle academic pressures more effectively.

Student Quote: *"The mindfulness sessions helped me deal with academic stress more effectively. I now approach challenges with a calmer mindset."*

Improved Cultural Sensitivity and Inclusion

The intervention increased students' awareness of the importance of cultural sensitivity and diversity in engineering projects. Many students reported a greater appreciation for inclusive teamwork practices.

Student Quote: *"Before this project, I didn't realise how important it was to consider cultural differences in team settings. It made me a better teammate and future engineer."*

Real-World Problem-Solving Skills

The project provided students with hands-on experience, allowing them to apply theoretical knowledge to real-world problems. This practical exposure enhanced their problem-solving skills and prepared them for future careers.

Student Quote: *"Working on real-world problems made the learning process more engaging. I felt like my work had a purpose beyond the classroom.*

Increased Confidence in Professional Interactions

The collaboration with industry mentors helped students build their confidence in presenting ideas and interacting with professionals. The feedback from mentors reinforced their skills and motivated them to pursue their career goals.

Student Quote: *"Presenting my ideas to industry mentors was intimidating at first, but their feedback helped me grow. I now feel more prepared for job interviews and professional discussions."*

Industry Feedback

Industry mentors provided valuable insights into the intervention's success. They recognised the collaboration's mutual benefits and appreciated the students' innovative approaches.

Industry Rep1: "The students' ability to think outside the box and address complex challenges was impressive."

Industry Rep2: "We gained fresh ideas from the students, and the collaboration was mutually beneficial."

Industry Rep3: "The emphasis on inclusivity and cultural sensitivity in the project was a refreshing approach, aligning well with our company's values."

DISCUSSION

The findings from the "Together Empowered" project highlight the effectiveness of integrating Positive Psychology Interventions (PPIs) and Equality, Diversity, and Inclusion (EDI) principles within the CDIO framework to address the challenges faced by engineering students. This discussion explores the broader implications of these findings in the context of engineering education, emphasising how holistic interventions can bridge the gap between technical training and essential soft skills development.

Addressing Well-Being in Engineering Education

Engineering education traditionally focuses on developing technical competencies, often overlooking the importance of students' emotional and mental well-being. The "Together Empowered" project demonstrates that addressing well-being through PPIs can significantly enhance students' overall academic experience. The improvement in Positive Emotions, Engagement, and Relationships categories within the PERMA model underscores the critical role that well-being plays in fostering academic motivation and resilience. These results align with existing research emphasising that students who feel emotionally supported and engaged are more likely to succeed academically and professionally (Seligman, 2011).

Enhancing Cultural Sensitivity and Inclusion

One of the unique aspects of the "Together Empowered" project was its focus on promoting cultural sensitivity and inclusion within engineering teams. The increased awareness of cultural differences reported by students highlights the importance of fostering inclusive teamwork practices in academic settings. In a globalised world, engineers must be equipped to work effectively in diverse teams, making cultural competence an essential skill. The

project's emphasis on EDI principles prepared students to navigate real-world engineering challenges with empathy and understanding, thus enhancing their employability.

Student Quote: *"Before this project, I didn't realize how important it was to consider cultural differences in team settings. It made me a better teammate and future engineer."*

The collaboration with industry mentors further reinforced the importance of inclusion in professional practice. Industry representatives valued the project's focus on diversity, recognising it as a critical factor in developing innovative and socially responsible engineering solutions.

Industry Quote: *"The emphasis on inclusivity and cultural sensitivity in the project was a refreshing approach, aligning well with our company's values."*

Bridging the Academia-Industry Gap

The project also addressed a long-standing challenge in engineering education—the gap between academic learning and industry expectations. By involving industry mentors in the intervention, students gained practical insights into real-world engineering problems and professional practices. This hands-on experience not only improved their technical skills but also helped them develop soft skills such as communication, teamwork, and problem-solving.

Student Quote: *"Working on real-world problems made the learning process more engaging. I felt like my work had a purpose beyond the classroom."*

The feedback from industry mentors was overwhelmingly positive, with many expressing appreciation for the students' ability to address complex challenges creatively. These interactions helped students build confidence in presenting their ideas and engaging with professionals, which is essential for career readiness.

Industry Quote: *"The students' ability to think outside the box and address complex challenges was impressive."*

The Role of Positive Psychology in Education

The integration of the PERMA model into the intervention provided a structured framework for enhancing student well-being. The statistical analysis of the PERMA scores showed significant improvements across all dimensions, indicating the effectiveness of PPIs in fostering emotional resilience and engagement. These results support the growing body of literature advocating for the inclusion of positive psychology principles in education to promote student flourishing (Butler & Kern, 2016).

The intervention also highlighted the importance of addressing mental health in academic settings. Many students reported that the mindfulness and stress management sessions helped them cope more effectively with academic pressures.

Student Quote: *"The mindfulness sessions helped me deal with academic stress more effectively. I now approach challenges with a calmer mindset."*

By promoting psychological well-being, the project created a supportive learning environment where students felt empowered to overcome challenges and achieve their goals.

IMPLICATIONS FOR FUTURE PRACTICE

The findings from the “Together Empowered” project have important implications for the future of engineering education. First, they demonstrate that well-being and EDI initiatives can be successfully integrated into technical programs without compromising academic rigour. Second, the project shows that university-industry collaborations can enhance the learning experience by providing students with practical exposure to professional practices and real-world challenges.

This project aligns particularly well with CDIO Standard 2 by explicitly targeting interpersonal and intrapersonal skills such as communication, teamwork, cultural competence, and well-being. It also exemplifies Standard 7 by providing integrated learning experiences through industry-based challenges and teamwork. The project's emphasis on PERMA-based active workshops reflects Standard 8. Importantly, the structured integration of these elements across the curriculum and collaboration with industry support Standard 3 and Optional Standard 1 (Sustainable Development).

Educational institutions must adopt a holistic approach that prioritises technical training and personal development to maximise the impact of such interventions. The CDIO framework provides an ideal structure for implementing these changes, as it emphasises the importance of developing well-rounded engineers who are prepared to address the complex challenges of the modern world.

Practical Recommendations for Educators

- Embed PERMA-based PPIs into design-implement projects: Introduce short reflective activities on gratitude, personal strengths, and goal-setting into project modules to foster well-being.
- Train facilitators in inclusive team management: Include EDI training for instructors to better support culturally diverse student groups.
- Collaborate with industry on socially impactful briefs: Encourage industry mentors to co-design challenges that combine technical complexity with social relevance, aligning with CDIO’s sustainability goals.
- Monitor well-being alongside academic progress: Use tools like the PERMA Profiler at the start and end of key modules to track student well-being and tailor support mechanisms.

Limitations and Future Research

While the results of the “Together Empowered” project are promising, it is important to acknowledge its limitations. The sample size was relatively small, and the intervention was conducted within a specific cultural and educational context. Future research could explore the long-term impact of similar interventions across different institutions and cultural settings.

Additionally, future studies could investigate the specific components of the intervention that had the greatest impact on student outcomes. This would help educators refine their approaches to promoting well-being and inclusivity in engineering education.

In conclusion, the “Together Empowered” project highlights the potential of integrating positive psychology and EDI principles within the CDIO framework to enhance student well-being, foster essential skills, and prepare students for successful careers in engineering. The findings underscore the importance of holistic education models that address both technical and

interpersonal competencies, paving the way for more inclusive and supportive learning environments in the future.

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