ŌTAUTAHI CHRISTCHURCH AOTEAROA NEW ZEALAND
35TH AUSTRALASIAN ASSOCIATION FOR ENGINEERING EDUCATION ANNUAL CONFERENCE
8-11 DEC 2024
THE ENGINEER AND THE WORLD

# Sustainability in Engineering Education using Multidisciplinary Case Studies - Educational Framework for Engineering Accreditation Exercises

Poovarasi Balan
*School of Engineering, Monash University Malaysia*
*Corresponding Author Email: Poovarasi.balan@monash.edu*

## ABSTRACT

### CONTEXT

The recent UN General Assembly meeting in September 2023 indicated that SDG 4 (Quality Education) is unlikely to achieve its targets by 2030. The lack of vigor in achieving the UN's target by higher institutions has been highlighted. An extensive literature review shows a lack of significant interest in exploring educational perspectives and outcomes in related fields.

### PURPOSE OR GOAL

The work proposed herein aims to address these gaps at an institutional level by integrating innovative sustainability integration, which can also enhance accreditation exercises. A training program for engineering academics will be developed, featuring multidisciplinary case studies from business, medicine, and science disciplines. This program will be delivered in hybrid mode (physical program and online mode).

### APPROACH OR METHODOLOGY/METHODS

Two approaches or methods were used in this project: 1) the development of training modules for engineering academics using a multidisciplinary approach in hybrid mode (physical and online mode) from expertise from different fields like medicine, psychology, science, and business and 2) Research data collection for a satisfaction survey that involves the experiences of the engineering academics who participated in the training program scheduled for October 2024.

### ACTUAL OR ANTICIPATED OUTCOMES

The multidisciplinary case studies developed from different fields/disciplines are anticipated to equip engineering academics with a broader perspective of SDG inclusion and mapping with structured assessment mechanisms in their dedicated teaching units. The physical training that includes LEGO sets usage from the business school, will help engineering staff to adopt similar approaches. The online training via Moodle will also share other case studies from medicine, psychology, and science, preparing engineering academics to learn more about SDG mapping and related knowledge.

### CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The engineering academics who participate in the training physically (one day) and subsequently enrol online through the Moodle platform are likely to gain enhanced knowledge, awareness, resources, and support for implementing new sustainability innovations in their classroom practices. They are expected to gather evidence of the teaching innovations they implement and report their findings on the Moodle platform as part of their ongoing learning.

### KEYWORDS

Sustainability, Engineering Education, Accreditation, Multidisciplinary case studies, Training

# 1. Introduction

The recent UN General Assembly meeting in September 2023 highlighted the disappointing progress toward achieving SDG 4 (Quality Education) by 2030. This underperformance is particularly evident in higher education institutions, especially in the context of sustainability engineering education. Extensive literature indicates a significant gap in the emphasis on educational perspectives and outcomes within this field (Arefin et al., 2021; Thürer et al., 2018).

UNESCO coordinated Education for Sustainable Development in higher education institutions from 2005 to 2014 (Arefin et al., 2021; Thürer et al., 2018). In 2015, UN SDGs were introduced. Despite these initiatives, a significant gap remains in training for staff development in sustainability education. Institutions must prioritize capacity building in teaching and learning sustainability among academics, as there is often a disconnect between curricula and the SDGs, which hinders effective integration (Mulder et al., 2012).

This study aims to address these gaps by developing effective training modules that integrate research gaps, innovative teaching pedagogies, and creativity-focused workshops. The lack of training for staff development in sustainability education necessitates a concentrated effort in capacity building. Institutions must prioritize teaching and learning in sustainability among academics, exploring new approaches that leverage creativity.

Project-based and problem-based learning have shown marked improvements in students' creativity (Wijnia et al., 2024; Yu, 2024). Integrating tools such as LEGO and mind mapping into these methodologies can further enrich the educational experience. In this study, we plan to implement training modules that combine these innovative pedagogies, fostering a more engaging and effective learning environment. This approach incorporates gamification strategies, utilizing LEGO and clay modeling alongside mind mapping to enhance sustainability education in higher education. This method has not been previously implemented at the current institution. By aligning with new engineering accreditation criteria in 2024, this initiative aims to bridge gaps and promote sustainability education at an institutional level and international policies on sustainable development.

# 2. Literature review

Sustainable development (SD) has become an emerging topic in addressing humanity issues recently. While higher education institutions (HEIs) play a critical role in the implementation of sustainability, such as the Agenda 2030 and the 17 SDGs, numerous challenges continue to hinder the efforts of SD integration in many HEIs, as reflected in a growing body of literature (Thürer et al., 2018).

A thorough analysis of the literature review shows that there has been a significant lack of systematic planning from the leadership in many HEIs to impede SD integration. The administrative role or the top-down approach is crucial in ensuring the success of SD implementation of SD integration (Leal Filho et al., 2018; Veiga Ávila et al., 2019). Hence, the leadership of an HEI must actively support SD integration for effective SD integration. In another study, the low density of national networks was identified due to insufficient interaction and communication among the stakeholders (students, staff, HEIs, government, and the general public), where the authors suggested that this might not support the effectiveness of SD integration, as collective efforts are required for the success of such a challenge (Vargas et al., 2019).

More importantly, resistance during SD implementation emerges due to a lack of knowledge and understanding of SD. Several issues such as lack of knowledge of circular economy, nonuniformity in terminology, the lack of a clear governance vocabulary for national policy frameworks, and Education for Sustainable Development (ESD) implications, have critically hampered the SD integration in HEIs (Fiselier et al., 2017; Mendoza et al., 2019). Without clear and proper guidelines, it is difficult for HEIs staff to arrive at a consensus on the approach to SD implementation. Finally, poor funding and lack of training among the HEIs staff are also the major

common obstacles in many HEIs, which resulted in SD integration not being able to be implemented effectively, due to difficulties when mobilizing HEI staff to include sustainability in the subjects that they offer (Kieu et al., 2016; Leal Filho et al., 2018, 2019). Without taking action to transform HEIs through leadership and staff training, HEIs could fall behind its SDGs and Agenda 2030, despite other efforts that have been taken in pursuing sustainable development.

Given the vitality of a top-down approach and the lack of training among HEIs staff, the objective of this project is to develop both physical and online training modules for engineering academics at Monash University, Malaysia to equip the staff with SD knowledge and practice, such that they will be able to introduce and integrate SD concepts into their respective courses during their teaching in the future. This is also in line with the study where an organization's environmental attitude after employee training has resulted in improvement in its performance in sustainable development (Ji et al., 2012), without overlooking the essence of top-down and bottom-up approaches in transforming a HEI (Ceulemans et al., 2011). Gamification approaches, such as the 2030 SDGs Game (Andreoni & Richard, 2024), have been shown to effectively promote interdisciplinary learning by fostering a deeper understanding of SDG interconnections through simulation-based, experiential learning (Pereira et al., 2024).

# 3. Methodology

Our project aims to develop and implement training modules for engineering academics using a multidisciplinary approach delivered in a hybrid mode, which is planned to be held in October. We decided to combine both physical and online training sessions in a hybrid mode to provide comprehensive learning opportunities.

## 3.1 Physical Training Sessions

The physical sessions, which will be held in October 2024, will feature innovative tools like talks related to research gaps, innovative teaching techniques to teach sustainability in different engineering disciplines (chemical, civil, mechanical, electrical, and robotics)' workshops (techniques using tools like LEGO, clay modeling and mind mapping). During the LEGO sessions, participants will explore using LEGO to illustrate and solve sustainability challenges in engineering contexts. These sessions aim to foster creativity and hands-on learning. Additionally, mind mapping will be used to help academics map SDGs to their assignments, offering a clear and structured method for integrating sustainability into their curriculum design. For the clay modeling sessions, participants will work in small groups of four, focusing on SDGs related to engineering, specifically SDG 8,9,10. Each group will use LEGO and clay to create models that reflect solutions to these goals, incorporating sustainability's social, environmental, and economic aspects. The idea is to get hands-on, encourage creative thinking, and work together to find practical ways to address real-world challenges tied to these SDGs. It's about making sustainability tangible through something as simple as clay and LEGO.

## 3.2 Online Training Sessions

For the online component, we will develop modules on Moodle, offering a platform for asynchronous learning. These modules will include principles of sustainability, detailed case studies from various disciplines, and interactive elements like forums and quizzes to keep participants engaged. A comprehensive case study will demonstrate the successful integration of sustainability into engineering education, providing a practical example for participants to adapt to their teaching contexts. A collaborative effort with the educational designers will be done collectively to make the Moodle site very interactive and exciting for academics to break free from their busy schedules and complete this as part of their professional development.

## 3.3 Research Data Collection and Analysis

We will use both qualitative and quantitative methods for data collection. Post-training, we will gather staff perceptions about the implementation of sustainability initiatives in their assessment

design through questionnaires. This feedback will guide future training content. Additionally, post-training activities, including monitoring and focus group interviews, will evaluate the extent of SD goals incorporated and identify areas for continuous improvement.

Staff surveys will explore their integration of sustainability into their units, the frequency of sustainability elements in assessments, and perceptions of higher education's role in addressing global challenges. The survey will include multiple-choice questions, Likert-scale evaluations, and open-ended questions. Similarly, student surveys will assess their perceptions of sustainability integration in their units, interest in elective courses on sustainability, and understanding of sustainability issues. Through this comprehensive approach, we aim to develop effective training modules that equip engineering academics with the tools and knowledge to integrate sustainability into their curricula. This initiative will enhance the quality of education and contribute to global sustainability goals.

# 4. Results & Discussion

Academic staff development in terms of training to share knowledge on the innovative pedagogies of teaching sustainability is vital. Continuous improvement based on the latest engineering accreditation will also be an important aspect of the delivery that resonates well with the change of time and student preferences. Hence, the project focuses on training the staff using various methods such as physical training, online training sessions, and post-training activities. The originally scheduled training in July was postponed to October, hence, the manuscript focuses on the planned activities with their progression.

## 4.1 Physical Training

During the planned physical training, a few modes of delivery will be focused such as small talks, discussions, and workshops. Several talks will focus on innovative pedagogy that was done under different disciplines. In this section, we will focus on one of the methods that will be delivered as one of the main activities of the workshop: the mind mapping technique. The nonlinear learning technique of mind mapping (Pudelko et al., 2012) is a new teaching and learning tool in higher education that supports student critical thinking. The radiant structure of a mind map, with its obvious branches, fosters associations. The employment of color to represent distinct categories might help increase these linkages (Driscoll et al., 2005). It has been determined that if students are given control over their map constructions, the maps positively impact student achievement because they embody metacognitive models with certain structures (Abi-El-Mona & Adb-El-Khalick, 2008).

The talk will focus on the use of mind maps as a creative technique as an integral part of the assignment design in a chemical engineering unit.

Figure 1 shows an example of sustainability mind mapping that was mapped with specific indicators of UN SDG goals is provided here. This example stems from the Particle Technology Unit offered at Monash University Malaysia for Chemical Engineering students in the 4th year.

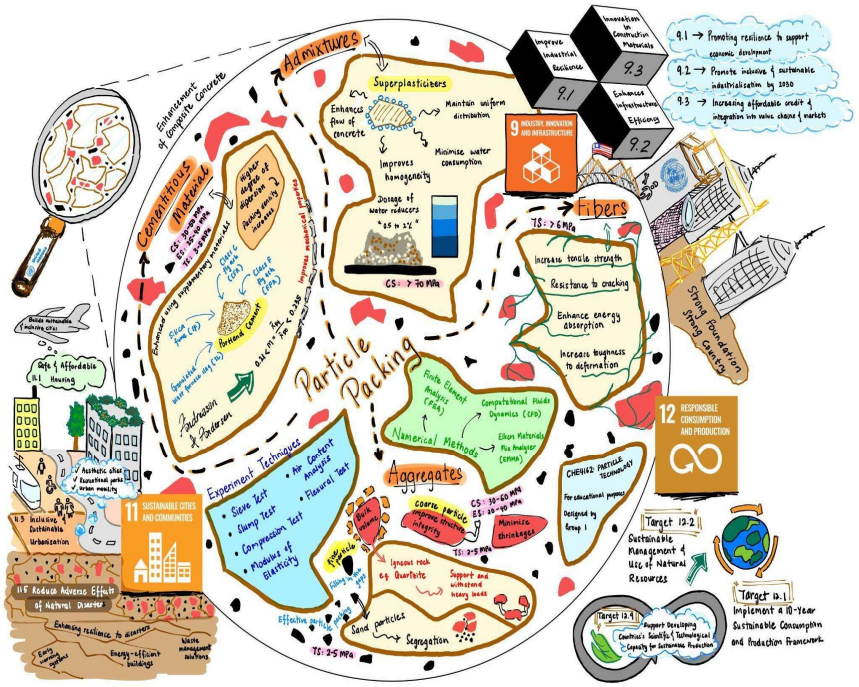


**Figure 1: Student assignment on UN SDG integration in Particle Technology engineering assignment using mindmap technique**

Based on the attributes identified in previous research (Zampetakis et al., 2007) as presented in Table 1 below, the mind map presented in Figure 1 was analyzed to be highly sophisticated from the classification provided in Table 1. The mind map produced is classified into different categories from what was created through mentorship during the classes: it is categorized to be case analysis (Level 3), words and drawings (Level 2), more than five colors (Level 3), and team assignment (Level 1). The current example will be shared with other academics during physical training to promote mind mapping as one of the techniques across multidisciplinary platforms to integrate sustainability.

**Table 1: Attributes of mind mapping planned for the physical workshop**

| Attribute | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Proposed Applications of Mind Maps | Descriptive | Integrative | Case analysis |
| Types of Mind Maps Presented | Only words | Words and drawings | Only drawings |
| Number of Colors Used in Mind Maps | One color | Three colors | Five colors |
| Ways Students Worked with Mind Maps | Team assignments | Individual assignments | - |

This practical application in the Particle Technology Unit enhanced their understanding of the subject matter and integrated sustainability indicators aligned with UN SDG goals, showcasing the interdisciplinary potential of mind mapping in higher education.

## 4.2 Feedback Questionnaire

The training was designed to provide educators with practical tools and strategies for embedding sustainability principles in their teaching and for raising awareness of the United Nations' SDGs. We have developed this feedback questionnaire to assess the training program's effectiveness and its relevance to participants. The questionnaire for the physical workshop will have Likert scale choice-based questions (Strongly agree to Strongly disagree) concerning the content evaluation and open-ended questions for personal evaluation.

**Table 2: Feedback Questionnaire for the Physical Training Workshop**

| Content Evaluation | Personal Evaluation |
|---|---|
| The training was relevant to my teaching needs. | How has this workshop enhanced your understanding of aligning Learning Outcomes (LO) and Program Outcomes (PO) with UN Sustainable Development Goals (SDGs)? |
| The exercises and discussions helped me learn the material. | How do you plan to integrate LO-PO-SDG alignment in your curriculum or academic activities using hands-on tools like LEGO, clay modeling, or mind mapping? |
| The training enhanced my learning and knowledge on the topic. | After this workshop, how do you intend to incorporate sustainability concepts in your academic programs, using LEGO, clay modeling, or mind maps to enhance student engagement? |
| I will use the knowledge and skills gained from this training | What challenges do you foresee when integrating sustainability concepts into your curriculum through interactive tools like LEGO, clay modeling, or mind maps? |
| I will apply the knowledge and techniques from the workshop to innovate my teaching methods | What workshop strategies using LEGO, clay modeling, and mind maps will help you address these challenges? |
| I would recommend this training to others | How effective are tools like LEGO, clay modeling, and mind maps in teaching sustainability and improving student understanding? |

## 4.3 Post-Training Questionnaire

In order to assess the challenges that engineering lecturers encounter when incorporating sustainability, surveys and focus group interviews for students and staff will be conducted for the chosen units. The surveys will guide the training content to enrich the educator’s knowledge to incorporate sustainability elements in their assessment designs. After a semester, the staff will be interviewed regarding the extent of sustainability elements successfully incorporated and the difficulties they encountered when innovating their assessment design. Additionally, students will be surveyed to understand their perception of the integrated sustainability in the units taught. This survey will also gauge the need and focus to be taken in undergraduate courses to improve the ability of graduates to meet their professional obligations (Crofton, 2000). Table 3 presents the questions framed for post-training questionnaires administered to staff members and students following the teaching period.

**Table 3: Staff Post-Training Questionnaire and Student Feedback after the teaching period**

| Perception Survey (Staff) | Student Survey |
|---|---|
| Do you integrate aspects of climate sustainability literacy into your unit, if yes, in what teaching activity? | This unit focuses on technical engineering knowledge with the complexity of problems embracing the concept of sustainable development |
| How often does your unit assessment include sustainability elements? | Given the opportunity, I would enroll in an elective unit specific to sustainability to develop professional knowledge and skill requirements in this area |
| To what degree do you agree or disagree with the following statements?<br>- My students value the integration of sustainability within the syllabus<br>- My students understand the importance of sustainability integration for future engineering employment | I enjoyed the integration and focus of the taught subject, taking into account sustainable development issues |
| What types of competencies related to sustainability do you target in your teaching? | Through the integrated sustainability elements taught, I have a deep understanding of the subject of sustainable development and realized the importance of preserving the environment and am always thinking about ways to achieve this |
| During the taught course where technical engineering knowledge was focused on, I consistently provided feedback with relevance to sustainable development and non-technical knowledge and skills | Which, if any, of the UN SDG goals do you foresee yourself contributing to upon graduation? |

# 5. Conclusions

This project underscores the importance of capacity building among engineering academics, emphasizing the need for sustainability in engineering education through a multidisciplinary approach. By involving experts from diverse fields such as medicine, psychology, science, and business, we have developed a robust training framework that aims to equip educators with the essential skills and knowledge needed to effectively incorporate sustainability into their curriculum.

The use of creative teaching and learning techniques, such as the upcoming LEGO workshops and mind mapping, has shown promise in engaging both staff and students in sustainability education. Empowering staff through targeted training sessions is crucial for the successful integration of sustainability into engineering education throughout their course of teaching. The upcoming training sessions at Monash University Malaysia, scheduled for October, aim to provide engineering academics with practical tools and resources for adopting sustainability-focused teaching practices. These sessions will facilitate the continuous professional development of educators, ensuring they remain equipped to meet the evolving demands of new engineering accreditation exercises.

By addressing the gaps identified in the literature, this project offers a structured approach to integrating sustainability into engineering education. By fostering a culture of sustainability and

innovation, we aim to prepare the next generation of engineers to tackle the complex challenges of the future, aligning with global sustainability goals and accreditation requirements.

## Acknowledgment

The authors would like to acknowledge Ronan Sim and group (CHE4162 S1 2024) from Chemical Engineering Discipline, Monash University Malaysia for the use of the assignment excerpt under the instruction and supervision of the course instructor, who is also the main author of this paper.

### References

Abi-El-Mona, I., & Adb-El-Khalick, F. (2008). The Influence of Mind Mapping on Eighth Graders' Science Achievement. *School Science and Mathematics*, *108*(7), 298–312. https://doi.org/10.1111/j.1949-8594.2008.tb17843.x

Arefin, Md. A., Nabi, Md. N., Sadeque, S., & Gudimetla, P. (2021). Incorporating sustainability in engineering curriculum: A study of the Australian universities. *International Journal of Sustainability in Higher Education*, *22*(3), 576–598. https://doi.org/10.1108/IJSHE-07-2020-0271Andreoni, V., & Richard, A. (2024). Exploring the interconnected nature of the sustainable development goals: The 2030 SDGs Game as a pedagogical tool for interdisciplinary education. *International Journal of Sustainability in Higher Education*, *25*(1), 21–42. https://doi.org/10.1108/IJSHE-11-2022-0378

Ceulemans, K., Prins, M. D., Cappuyns, V., & Coninck, W. D. (2011). Integration of sustainable development in higher education's curricula of applied economics: Large-scale assessments, integration strategies and barriers. *Journal of Management & Organization*, *17*(5), 621–640. https://doi.org/10.5172/jmo.2011.17.5.621

Crofton, F. S. (2000). Educating for sustainability: Opportunities in undergraduate engineering. *Journal of Cleaner Production*, *8*(5), 397–405. https://doi.org/10.1016/S0959-6526(00)00043-3

Driscoll, M. P., Driscoll, A., & Forsyth, N. (2005). *Psychology of learning for instruction* (3rd ed.). Pearson Allyn and Bacon.

Fiselier, E. S., Longhurst, J. W. S., & Gough, G. K. (2017). Exploring the current position of ESD in UK higher education institutions. *International Journal of Sustainability in Higher Education*, *19*(2), 393–412. https://doi.org/10.1108/IJSHE-06-2017-0084

Ji, L., Huang, J., Liu, Z., Zhu, H., & Cai, Z. (2012). The effects of employee training on the relationship between environmental attitude and firms' performance in sustainable development. *The International Journal of Human Resource Management*, *23*(14), 2995–3008. https://doi.org/10.1080/09585192.2011.637072

Kieu, T. K., Singer, J., & Gannon, T. J. (2016). Education for sustainable development in Vietnam: Lessons learned from teacher education. *International Journal of Sustainability in Higher Education*, *17*(6), 853–874. https://doi.org/10.1108/IJSHE-05-2015-0098

Leal Filho, W., Pallant, E., Enete, A., Richter, B., & Brandli, L. L. (2018). Planning and implementing sustainability in higher education institutions: An overview of the difficulties and potentials. *International Journal of Sustainable Development & World Ecology*, *25*(8), 713–721. https://doi.org/10.1080/13504509.2018.1461707

Leal Filho, W., Shiel, C., Paço, A., Mifsud, M., Ávila, L. V., Brandli, L. L., Molthan-Hill, P., Pace, P., Azeiteiro, U. M., Vargas, V. R., & Caeiro, S. (2019). Sustainable Development Goals and sustainability teaching at universities: Falling behind or getting ahead of the pack? *Journal of Cleaner Production*, *232*, 285–294. https://doi.org/10.1016/j.jclepro.2019.05.309

Mendoza, J. M. F., Gallego-Schmid, A., & Azapagic, A. (2019). Building a business case for implementation of a circular economy in higher education institutions. *Journal of Cleaner Production*, *220*, 553–567. https://doi.org/10.1016/j.jclepro.2019.02.045

 

Mulder, K. F., Segalàs, J., & Ferrer-Balas, D. (2012). How to educate engineers for/in sustainable development: Ten years of discussion, remaining challenges. *International Journal of Sustainability in Higher Education*, *13*(3), 211–218. https://doi.org/10.1108/14676371211242535

Pereira, G., Berti, I. C. L. W., Andrade, M., Barros, V., Caetano, A. M. P., Silva, R., Valente, V., & Paletta, F. C. (2024). Teaching to Research: The Use of Gamification in Pedagogical Experiences. In C. Silva, S. Silva, D. Mota, & P. Peres (Eds.), *Smart Learning Solutions for Sustainable Societies* (pp. 179–191). Springer Nature. https://doi.org/10.1007/978-981-97-0661-7_13

Pudelko, B., Young, M., Vincent-Lamarre, P., & Charlin, B. (2012). Mapping as a learning strategy in health professions education: A critical analysis. *Medical Education*, *46*(12), 1215–1225. https://doi.org/10.1111/medu.12032

Thürer, M., Tomašević, I., Stevenson, M., Qu, T., & Huisingh, D. (2018). A systematic review of the literature on integrating sustainability into engineering curricula. *Journal of Cleaner Production*, *181*, 608–617. https://doi.org/10.1016/j.jclepro.2017.12.130

Vargas, V. R., Lawthom, R., Prowse, A., Randles, S., & Tzoulas, K. (2019). Sustainable development stakeholder networks for organisational change in higher education institutions: A case study from the UK. *Journal of Cleaner Production*, *208*, 470–478. https://doi.org/10.1016/j.jclepro.2018.10.078

Veiga Ávila, L., Beuron, T. A., Brandli, L. L., Damke, L. I., Pereira, R. S., & Klein, L. L. (2019). Barriers to innovation and sustainability in universities: An international comparison. *International Journal of Sustainability in Higher Education*, *20*(5), 805–821. https://doi.org/10.1108/IJSHE-02-2019-0067

Wijnia, L., Noordzij, G., Arends, L. R., Rikers, R. M. J. P., & Loyens, S. M. M. (2024). The Effects of Problem-Based, Project-Based, and Case-Based Learning on Students' Motivation: A Meta-Analysis. *Educational Psychology Review*, *36*(1), 29. https://doi.org/10.1007/s10648-024-09864-3

Yu, H. (2024). Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon*, *10*(6), e27706. https://doi.org/10.1016/j.heliyon.2024.e27706

Zampetakis, L. A., Tsironis, L., & Moustakis, V. (2007). Creativity development in engineering education: The case of mind mapping. *Journal of Management Development*, *26*(4), 370–380. https://doi.org/10.1108/02621710710740110

## Copyright statement