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Emotional Intelligence for sustainable engineering education: incorporating soft skills in the capstone chemical engineering capstone design project

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Abstract

Chemical engineering students in universities across the world are involved in at least one chemical engineering design project during their studies. Traditionally, the concept of design in chemical engineering education has been associated with the design of processes, equipment and products, with extensive focus in technical knowledge, creative thinking, problem solving, common sense and efficiency. But are these skills enough for chemical engineering graduates to shine and make a difference in their careers?

While engineering education focuses on the establishment of hard skills, it pays little or no attention to the soft skills that are necessary for the careers of engineering graduates. Conversely, sustainable engineering education considers soft/social skills, such as the ability to work in teams, empathy, self-motivation and self-regulation, a key element of engineering curricula.

In order to maximise the potential of sustainable engineering education and prepare the students for the real work life challenges, in a team-driven learning format, as opposed to a student-centred approach, a "collaborative working strategy" (Mitchell, 2008) was introduced to the capstone design project. A personality mapping and a set of collaborating working values and behaviours were introduced as part of the project, in order to examine the extent to which emotional intelligence enhances collaborative teamwork in engineering education.

More specifically, the students were asked to map their personalities and working styles in order to explore the dynamics of their team. The personality test that was used for this purpose was "The Insights Discovery, the colour personality test", based on Carl Jung's model for personality types. Having mapped their working style strengths and weaknesses, the teams were asked to adhere to a set of values including 1) common goal and unity of purpose, 2) team trust, 3) interdependence, 4) accountability and 5) effective feedback. These values were used as a guideline for effective communication, while the students were asked to monitor, list and reflect on the collaborative working behaviours of them and their peers, as part of their weekly tasks.

The preliminary findings of this ongoing study have indicated that emotional intelligence enhances the effectiveness of project team working, providing the necessary evidence that emotional intelligence holds a dominant role in sustainable engineering education and should be part of the engineering curriculum.

1 Introduction

Sustainability is a philosophy of personal development, professional life and community engagement and is linked to soft skills, moral values and ethos (de La Riva de la Riva et al., 2015). The concept of sustainability in engineering education has been well addressed and linked to climate change,

environmental impact, resource and component depletion, mainly focusing on sustainable development (e.g. Desha et al, 2007; Ashford, 2004; Thompson, 2002; Tryggvason and Diran, 2006; Sanderson, 2008; Tsalaporta et al. 2018).

Emotional Intelligence is the ability to understand, use, manage emotions and empathise in order to communicate effectively, overcome challenges and defuse conflict. Emotional intelligence has been associated with enhanced individual and group work performance (e.g. Goleman, 1998a; Goleman, 1998b; Goleman et al, 2002; Druskat and Druskat, 2006). Boyatzis et al. (2016) have conducted a research study assessing the effectiveness of engineers at a multinational manufacturing company along with their IQ, personality, and emotional intelligence. They concluded that emotional intelligence was the only factor to predict the effectiveness of the participants. Despite the evidence, emotional intelligence has been underestimated and almost excluded from engineering education.

Recently, researchers have linked sustainable development to emotional intelligence, considering emotional intelligence a dimension of sustainability, therefore a key element in sustainable engineering education. Bheekhun et al. (2018) have concluded that a blend of engineering, scientific and technical knowledge, in addition to management, innovation, economic, communication, and more importantly ethical and moral knowledge and skills are the basics for designing a sustainable engineering curriculum.

2 Emotional Intelligence in the chemical engineering capstone design project

The work profile of chemical engineers has drastically changed since the industrial revolution. In the past, chemical engineering was a solo job and chemical engineers were classified as highly intelligent, technically rigorous and innovative individual contributors, working independently to provide solutions in the space of a lab/factory/production line. Nowadays, chemical engineering has moved beyond this simplistic approach. Contrary to old images and perceptions, chemical engineers are part of and lead multidisciplinary/transdisciplinary teams, their working spaces are not necessarily labs or factories and they hold meetings with diverse clients in multi-cultural contexts, being at the front line of their companies.

In order to meet the new needs of their profession, some essential skills for chemical engineering graduates when entering the workforce are social skills, such as the ability to work in teams, empathy, self-motivation and self-regulation. The chemical engineering capstone design project is the opportunity for chemical engineering students to work effectively as part of a team and develop soft skills such as self-awareness, self-management, empathy, and relationship awareness.

The capstone design project (PE4050) of the department of Process and Chemical Engineering of UCC focuses on the design of an industrial plant, a product or a process in a team-driven learning format, as opposed to the traditional single student-centred approach; therefore, it is the perfect platform to implement real work life conditions and challenges, to monitor the impact of emotional intelligence and relate it with team performance. Fourth year students (either Bachelor's or Master's) are working in teams of 5 or 6 in order to create their own manufacturing facility. The incorporation of emotional intelligence in the design project is aiming to allow the students to reinforce and apply subject knowledge, whilst developing key soft skills such as teamwork and communication; the design tasks are aiming to develop critical thinking, problem solving, active learning, sense of responsibility, safety, environmental sensitivity and energy saving, but also to determine how well they manage themselves and work with others.

3 Methodology

A case-study approach was adopted for in-depth analysis of the role of soft skills on the capstone design project. Initially, the profile of the class was analysed and the students were allocated in groups. More specifically, there were 64 students, 47 of whom were male and 17 female, and were allocated in 12 groups of 5 or 6 members. Instead of working in teams of their preference, the students were randomly allocated in groups, in order to simulate real life working conditions. 12 topics were introduced to the 12 groups and the newly developed groups were asked to choose 3 topics of their preference.

At this early stage for the groups, the choice of the topics was an actual challenge; this was the driving force for the incorporation and investigation of the collaborative working strategy (Mitchell, 2008), as an educational tool in team projects such as the design project. More specifically, a personality mapping (Insights Discovery Test) and a set of collaborating working values and behaviours were introduced as part of the project, in order to examine the extent to which emotional intelligence could enhance collaborative teamwork in engineering education.

3.1 The Insights Discovery Test (http://www.seveninstitute.co.uk/insights-discovery/)

In order to explore their working styles as well as the dynamics of their groups, the students were asked to map their personalities and behaviours. The personality test that was used for this purpose was "The Insights Discovery, the colour personality test", based on Carl Jung's model for personality types. As seen in Figure 1, this personality test uses 4 colours (blue, red, green and yellow) to describe different personalities:

Fiery Red: Individuals with a high amount of fiery red are competitive, strong minded and focused on results, while the interaction with others is characterized by determination.

Sunshine Yellow: Enthusiastic personalities with strong social skills, they encourage participation and they enjoy to be involved in group work.

Earth Green: Altruism could well describe this type of personality; they are seeking harmony, are caring and patient.

Cool Blue: Accuracy, observation and preciseness and a genuine desire to know and understand are some of the characteristics of these individuals.

Each person is a unique combination of these four colours, which determines one's personal style and behaviour at work. The students had to complete a short questionnaire, reflect on their strengths and weaknesses based on their unique colour profile and finally share their profile with their group as well as the lecturer, in order to help others to understand their personality and work together in harmony. The results are provided and discussed later.

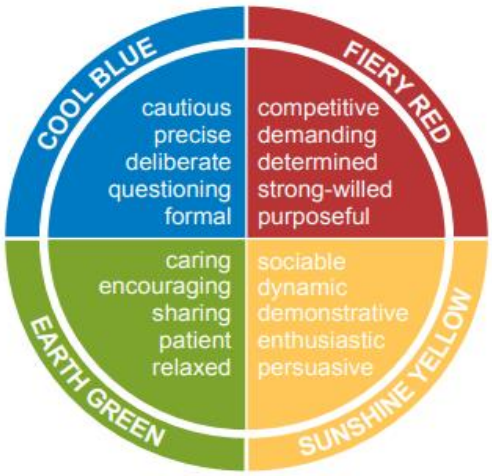

Figure 1. Colour personality mapping

3.2 Collaborative working strategy

Table 1. Team Assessment Tool (TAT) for assessing the collaborative working strategy in the capstone design project (PE4050) of UCC

Team assessment Tool (TAT)	**Positive**	**Neutral**	**Negative**
Sense of understanding of Emotional Intelligence (EI) and its importance			
Emotional Intelligence is linked to sustainability			
Sense of team			
Recognising others feelings			
Trust among team members			
Empathy among team members			
Professionalism among team members			
Understanding of competencies of team members			
No blame culture in the team			
Peer learning among team members			
Confidence that the design project would be delivered on time			
Confidence that the quality of the delivered design project would be good			
Belief that the collaborative working strategy set the basis for effective team communication			
Belief that the collaborative working strategy helped to overcome problems			

Having mapped, shared and discussed their working style strengths and weaknesses, the twelve groups were asked to adopt and apply the collaborative working strategy as described by Mitchell (2008). The twelve groups were asked to adhere to a set of values including 1) common goal and unity of purpose, 2) team trust, 3) interdependence, 4) accountability and 5) effective feedback. These values were used as a guideline for effective communication, while the students were asked to monitor, list and reflect on the collaborative working behaviours of them and their peers, as part of their weekly tasks.

More specifically, the students were asked to adopt some effective team working behaviours, individually but also as part of their group, as follows:

- Act as a team, not as a group: set a structure in your team by choosing (or not choosing) a team leader;
- Listen effectively: listen to understand, not to respond;

- Share and discuss ideas before taking action;
- Consider other team member's views, experiences and see things from their perspectives;
- Be clear: explain what you expect from others and understand what they expect from you;
- Distribute responsibilities and do what you agreed to do;
- Be professional: personally commit to the delivery of the project;
- Recognize achievements;
- Challenge below standard behaviours in a constructive manner;
- Be open with your problems and try to resolve them together as a team.

These behaviours aimed to provide a structured context in which individual and group emotional intelligence was enhanced in a direct or indirect manner, with the anticipated benefits being: a) sense of team/enhanced team spirit, b) effective team work c) improved communication, d) conflict resolution and e) team learning.

At the end of the semester, the students had to evaluate to which extent the shared values and behaviours had accomplished their purpose and to which extent the anticipated benefits were met, by completing a questionnaire (Team Assessment Tool) that was developed for the purposes of this article, as well as writing a personal reflection. The Team Assessment Tool (TAT) has the form of a quick questionnaire and aims to assess to what extent the collaborative working strategy is applicable in the capstone design project. The TAT is presented in the table above. The personal reflections provided a number of common findings which are presented below.

5 Results and Discussion

5.1 The Insights Discovery Test

The Insight Discovery Test mapped very accurately the working styles of the students, proving that it is a very useful tool for both the students and the lecturer. Through this test, the students were able to recognise their individual strengths and weaknesses and associate them with their working styles, as well as the working style of their group peers. The lecturer was able to use the personality mapping to predict the dysfunctional groups and in the future prevent this dysfunctionality by ensuring that there is a variety and balance among the personality colours in each group.

More specifically, the personality profiles of a group of five students are presented unanimously in Figure 2. In this team, the dominant colours of the team members are blue, green and yellow. The red is present but not dominant in any of the team members. This team was well organised, with all the team members being very diligent. This was reflected in the meetings with the lecturer/mentor, where the team was using this time effectively, looking at the project holistically, having prepared questions and keeping notes. However, while the team members were motivated and hard-working, there was a lack of leadership and confidence in their work.

Other teams had the opposite problem. More specifically, there were three teams with the majority of the members having a red type of personality. In the meetings with these teams, it was obvious that there were different views among the team members and occasionally were using this time to discuss and take decisions. Moreover, the members of these teams had a tendency to focus on the individual element (design memo) of their work, as opposed to the actual design project.

The teams, with the yellow element dominant, had a tendency to underestimate the amount of work associated with this module. In the meetings with the lecturer/mentor, the team members were overoptimistic, with almost a lack of sense of reality, regarding the deliverables of the project. On the other hand, the teams with green element dominant, had a tendency to focus on less important aspects of the design project, showing limited ability to set priorities.

The outcomes from this ongoing research are at a preliminary stage and more samples are required in order to come to a safe conclusion. However, the Insights Discovery Test could be used retrospectively, prior to the formation of the groups at the beginning of the semester, in order to investigate to what extend a colour personality balance could be beneficial in this team project.

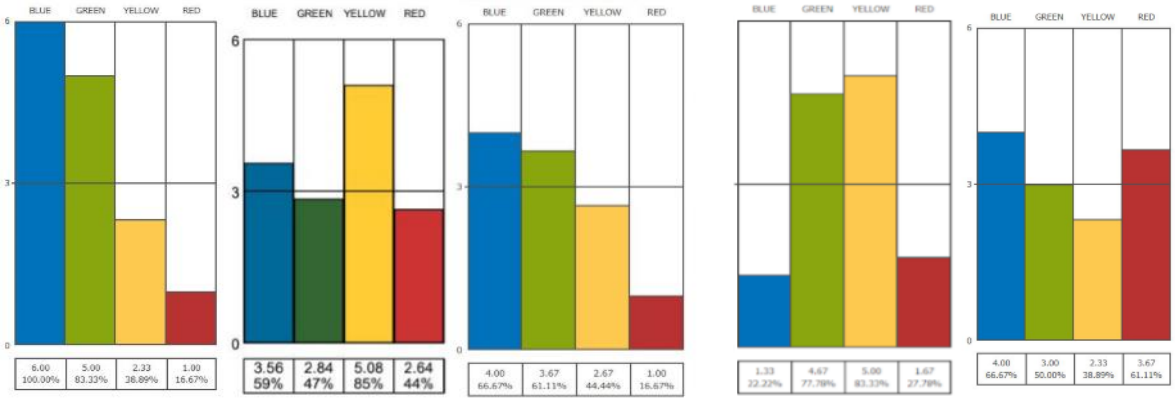

Figure 2. Colour personality mapping of a group of five students

5.2 Collaborative working strategy

The Team Assessment Tool (TAT) provided a baseline for the assessment of the collaborative working strategy. The students found the effective team working behaviours useful, with their experience and feedback being very positive, as seen in Table 2. The vast majority of them found the collaborative working strategy very beneficial regarding team structure, communication and team members' relationships, reflecting very positively in the productivity and the quality of their work.

This outcome was further supported by the students' personal reflections that provided very useful insights in relation to the dynamics of their groups. A summary of the findings of the personal reflections are:

- The biggest challenge of the design project is group work;
- Listening to understand was a very difficult skill to develop;
- Working effectively in groups is essential for engineers;
- Peer learning is a strong element of group work;
- Interpersonal skills like patience, communication and empathy are key elements for engineers to effectively complete group projects;
- The design project was the most challenging but also rewarding experience of the curriculum.
- Emotional Intelligence is part of sustainable thinking and sustainable engineering.

Table 2. Team Assessment Tool – results

Team assessment tool (TAT)	**Positive (%)**	**Neutral (%)**	**Negative (%)**
Sense of understanding of Emotional Intelligence (EI) and its importance	95.5	3	1.5
Emotional Intelligence is linked to sustainability	98.5	1.5	0
Sense of team	80	4.5	15.5
Recognising others feelings	63	6	31
Trust among team members	66	4.5	29.5
Empathy among team members	64.5	26.5	9
Professionalism among team members	61.5	6	32.5
Understanding of competencies of team members	54	31.5	14.5
No blame culture in the team	57	30	13
Peer learning among team members	70.5	3	26.5
Confidence that the design project would be delivered on time	94	0	6
Confidence that the quality of the delivered design project would be good	51	22	27
Belief that the collaborative working strategy set the basis for effective team communication	98.5	1.5	0
Belief that the collaborative working strategy helped to overcome problems	95.5	4.5	0

6 Conclusions

This paper has investigated the incorporation of soft skills in the capstone chemical engineering capstone design project, as part of a sustainable engineering curriculum. Emotional intelligence, as a dimension of sustainability, has enhanced the effectiveness of project team working.

The outcomes from this ongoing research are at a preliminary stage and further research is required in order to come to a safe conclusion. However, the Insight Discovery Test has mapped very accurately the working styles of the students, proving that it is a useful tool in engineering education. The collaborative working strategy and the TAT provided a structured context in which individual and group emotional intelligence was enhanced in a direct or indirect manner.

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