Strategies for teaching idea generation for project-based learning and adapting these approaches to an on-line environment

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ABSTRACT: Problem solving is a key skill for engineers and innovative problem solving relies on effective idea generation. Over several years a blended learning approach to teach idea generation has been developed at Massey University, Palmerston North, New Zealand. This article describes the approach which includes an on-line pre-workshop module followed by an in-person workshop. In the workshop students work in teams and generate ideas for a given scenario using different idea generation methods. Ideas are then shared, and students reflect on the methods they have used. In 2021 the in-person workshop was moved on-line due to a Covid-19 lockdown. The workshop was redesigned to use breakout rooms in Zoom and Google Docs were used to enable students within the team to share their ideas in a safe environment, while at the same time allowing staff to monitor progress and offer assistance when needed. While the on-line workshop was successful at teaching idea generation techniques, it was not possible to replicate the same environment as the in-person workshop.

Keywords: Active learning, idea generation, project-based learning, on-line learning

INTRODUCTION

The ability to solve complex problems is critical in the engineering field and is highlighted by accreditation bodies as a requirement for graduate engineers [1]. Problems encountered by engineers are often complex and require innovative and creative solutions to be developed. To enable creative solutions, it is vital that engineers can develop many alternative solutions and to *think outside the box*.

Effective idea generation is the foundation for success to ensure that all options of a problem are explored, and it is not just the first idea thought of that is seen as the solution, and therefore, this gives a better chance of success. The success of idea generation usually depends on the quality of the best opportunities identified rather than the quantity [2]. This highlights the importance of idea generation as a key skill for graduate engineers.

The strong focus on technical aspects of programmes can mean engineering students struggle to come up with creative ideas [3-5]. Students can have a tendency to screen their ideas as they go, and therefore avoid ideas which may not be technically feasible [6] without examining the ideas in full.

It has been suggested for effective creative thinking and idea generation a supportive and safe environmental is important, so that students will share their ideas [7]. Students may not be comfortable sharing innovative ideas in case they are seen as foolish, so staff need to ensure that risk taking with their ideas is encouraged [8]. To facilitate this, working in teams collaboratively and generating ideas to solve problems has been suggested [9]. This suits the project-based learning approach which has been adopted within the engineering programme at Massey University in Palmerston North, New Zealand.

The Covid-19 pandemic has resulted in learning needing to move on-line over the last two years. The compatibility of on-line delivery with activities which require hands-on learning has been identified as being particularly challenging [10]. As a result, there is a need for staff to create innovative ways of facilitating meaningful on-line learning [11].

Over several years the approach to teaching idea generation has evolved and this article reports on the successful active learning approach which has been developed. In the article, the authors also discuss how this approach was modified to suit an on-line environment due to Covid-19 lockdown and some of the unique challenges that this causes when teaching idea generation.

CONTEXT

The Massey University Bachelor of Engineering (Honours) programme is based on a series of project-based learning (PBL) courses that form 25% of the programme in each year and is termed the *project spine*. The programme is designed to address not only the need for graduates who are *rounded* with stronger *sof*t or professional skills around teamwork, ethical considerations, sustainability, management and leadership, life-long learning and have a greater practical appreciation of the theoretical knowledge that they were being taught, but also meet the graduate attributes of the Washington Accord WA6 - WA12 [1] that are part of the graduate profile. PBL is believed to develop these skills more than a traditional learning approach [12][13], and by having PBL in each year of an engineering programme it follows the fourth principle towards guiding the transformation of engineering education for the greater engagement of students [14]. The programme has:

- a focus on project-based learning in teams across all 4 years (25% of the programme),
- where the projects are designed to integrate and apply knowledge learned in a specific year, and
- where the projects are designed to introduce and embed problem solving principles in a range of contexts, and
- where complexity and autonomy increase across the four years - leading to the final year capstone and research projects.

In years 1 and 2 the students are formally introduced to methods of idea generation in two successive courses, each with a different context. The first course is 247.114 Science and Sustainability for Engineering and Technology, which is a project-based, interdisciplinary course introducing students to the applied scientific thinking and theories that underpin the relationship between applied science and sustainability, with an exploration of how the Treaty of Waitangi underpins a partnership between Pākehā and Māori, focussing on ways in which applied science can be guided by Tikanga Māori (including culture, ethics and knowledge systems), where by examining the interactions between human, cultural, environmental and technological systems, students develop their critical thinking, communication and literacy skills as they develop solutions to contemporary challenges in sustainability in a team-based project.

Each team of 3-5 students select a New Zealand based industry from the provided list. The student team investigates the life-cycle of their chosen industry, determining the inputs and outputs including waste at each stage of the life-cycle. With reference to the United Nations Sustainability Development Goals the student team uses introduced methods of decision-making and selection to choose what they consider to be the stage of the life-cycle could be modified to improve the sustainability of the industry. Once an area for improving the sustainability of the industry is chosen the student team defines their opportunity or problem statement and uses idea generation techniques to create possible solutions for addressing their opportunity statement. After screening of ideas each student takes one idea to develop, further adding more detail, evaluate and communicate the possible solution.

The second course is 228.211 Engineering Practice 3: Product Development, where the development of new and improved products is a key role of most practising engineers. The course provides a structured process and tools required for successful product development in the context of an applied project.

In this course, the students chose their own project team and then each team chooses a New Zealand company from the provided list to focus on. The student team needs to identify an opportunity for developing a new product for the company and work through the problem-solving process using the product development methods to deliver a product concept in a final presentation to a panel, and in a final report that communicates a recommendation to the company to further develop the product concept or not with reasoning based on the team's research and evaluation. The project uses idea generation methods at several steps in the process to generate opportunities for development, to generate ideas for the selected opportunity to create a product concept and to iterate this process as more is learned from stakeholder research.

TEACHING IDEA GENERATION USING BLENDED LEARNING

The teaching of idea generation methods in the Bachelor of Engineering (Honours) programme at Massey University has evolved from a lecture delivering an explanation of the number of techniques with students being expected to use a number of techniques in the project, to blended learning using on-line material and an interactive workshop, where students practice the techniques and through presentation can compare the results. The on-line pre-workshop material with workshop activity was first used in the second project course 228.211 Engineering Practice 3: Product Development (as the mature course), though idea generation methods are first introduced in the first-year course 247.114 Science Sustainability for Engineering and Technology. The second-year course idea generation workshop is a recap for the first-year learning but will be used to illustrate the on-line pre-workshop and face-to-face workshop teaching of idea generation. The structure of the second-year course means that idea generation methods are covered in week 2 of the twelve-week semester course.

Idea generation methods are introduced in the on-line pre-workshop book – first a systematic process for idea generation is shown by Ulrich and Eppinger [15], followed by an introduction or recap of several selected techniques from the large number of methods available (for example; see in Silverstein et al [16]). The techniques that are covered will mostly be those that students will recognise or are most common, such as brainstorming (including brainwriting and mindmapping), Six Thinking Hats, SCAMPER, analogy including biomimicry and synectics.

In the in-person workshop the students are encouraged to sit with their teams. The students are reminded of the different techniques and any questions are answered about how they are used. A scenario is introduced to the class related to the example used throughout the course in workshop activities and the students are given self-adhesive note pads and marker pens. As an example, the in-person workshop delivered for the second-year course is explained below.

- Teams need to generate ideas and think of some selection criteria. The scenario given to students is:
  - The company is a confectionery manufacturer specialising in chocolate and based in New Zealand. Their brand is the second-largest chocolate brand in New Zealand and is estimated to hold 41% of the local block market. Approximately 30% of their production is now exported;
  - The company exports products to Australia, Canada, Malaysia, Singapore, Indonesia, Philippines, China, Hong Kong, South Korea, Japan, the Middle East, Kenya and many Pacific Islands;
  - Senior Management have identified that it is time to tackle the British and European market and establish themselves as a world leading brand;
  - What ideas are there to fit this scenario?
- The following methods are used to generate ideas for this opportunity:
  - Brainstorming (two teams combine for the exercise to give the recommended 8-10 people for brainstorming activities);
  - Brainwriting (two teams);
  - SCAMPER (two teams);
  - Synectics (two teams);
  - Six Thinking Hats (two teams);
- Teams have 15-20 minutes before each team presents their ideas and the criteria for selection.

Once the exercise is completed a member from each team writes the ideas generated by the team on the whiteboards with the method used identified. The results are reviewed in a class discussion and the students reflect on what has been learned about idea generation. An example of the ideas generated is shown in Figure 1.

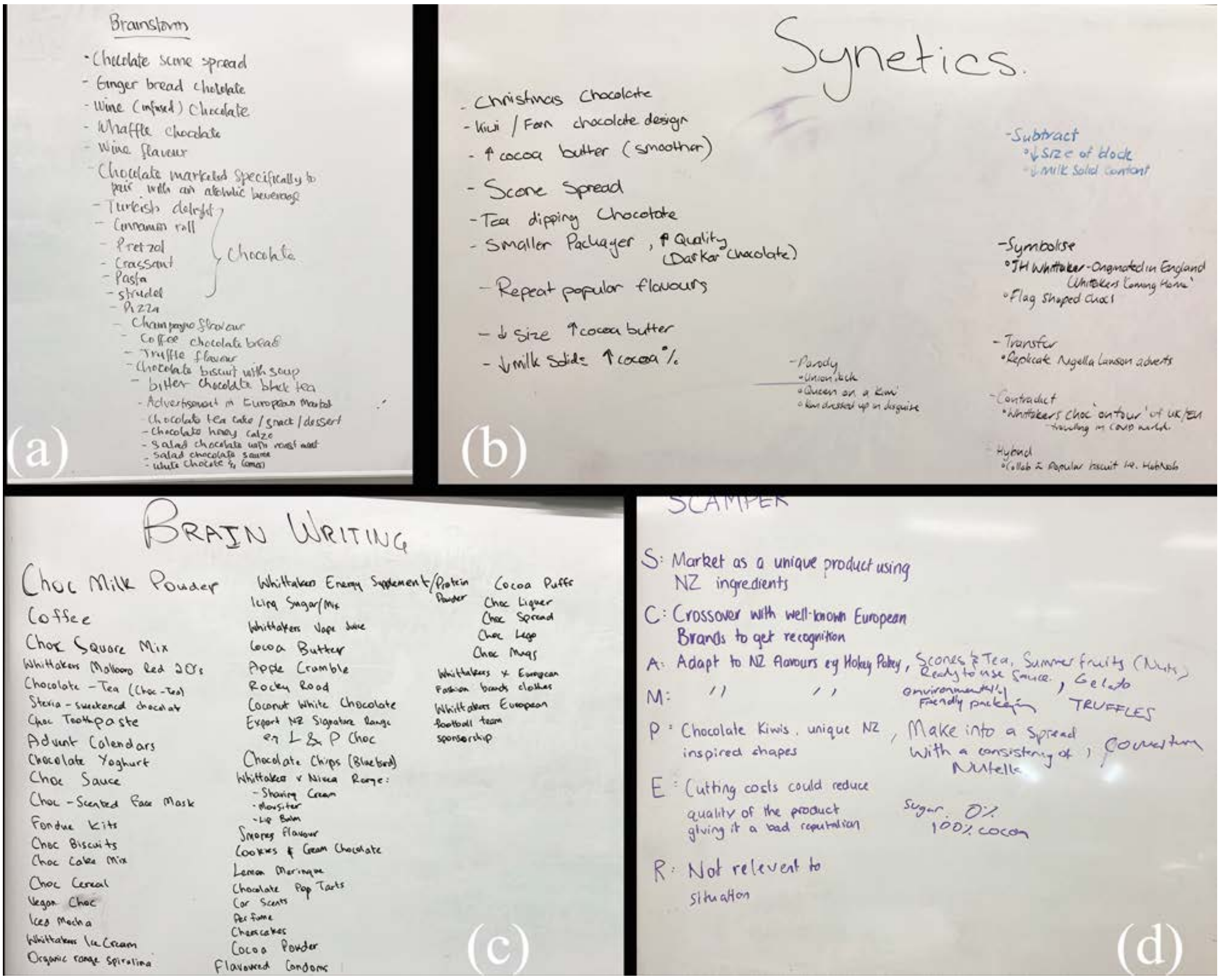

Figure 1: A sample of ideas generated by student teams using four different techniques: a) brainstorming; b) synectics; c) brainwriting; and d) SCAMPER.

Although it is dependent on the team, their use of the method and their interest in the activity, there can be about 200 ideas produced in a class of ten teams (about 40 students), with some repetition between the different techniques but also with many ideas unique to the method used. Brainstorming and brainwriting tend to produce the most ideas.

It was observed that teams using a team approach to brainstorming (everyone collaborating together) tended to have fewer ideas than teams using a more hybrid approach, such as brainwriting (everyone generating ideas independently and then collaborating or building on the ideas generated by the other team members) and this is consistent with some theories on idea generation and the concept of *production blocking* (for example; see Diehl and Stroebe [17]). It was more interesting as teachers that the students using techniques such as SCAMPER and synectics, having resisted the idea of using them, found the methods very useful even in the limited scenario being used and became determined to use them in their own projects along with the more *traditional* method of brainstorming.

This workshop activity was thought to be effective in exposing the students to the different methods possible for idea generation and enabled them to use more than one method when generating ideas. Using the above example from the second-year course in 2021 there were 13 groups - 11 groups reported using brainstorming and two reported using brainwriting for their primary idea generation method used. However, only five groups reported using another method in addition to their primary method, these being mindmapping: (1), SCAMPER (3), synectics (1), outside sources (2), and interestingly empathy maps from the Design Thinking Toolbox (1). Two groups used three methods. The groups using multiple methods reported between 40 and 60+ ideas generated, which was higher than other teams though one group using Brainwriting in a hybrid manner (ideas were shared) generated over 46 ideas. Some methods used were not recognised as idea generation by the students, such as multiple ideas generated through sketching. Although it is possible to report these numbers it is only possible to infer that teams using multiple methods seem likely to generate more ideas and there are no observations on the quality of these ideas and whether it led to better project results.

Although it was expected that student teams would use idea generation multiple times throughout the second-year project at different stages as shown to them, this did not appear to happen although it might be that they did not write it into their project reports. The effectiveness of idea generation methods also depends on the selection criteria and methods used by students. After a workshop activity recapping idea screening processes, all teams used a selection matrix (for example, a Pugh Matrix, Chapter 14 from Pugh et al [18]) to select ideas to investigate further although a number of teams used an initial pass/fail matrix first to reduce the number of ideas to consider.

Overall, it is thought this workshop activity for idea generation has been successful in allowing the students to explore potential opportunities and solutions for their problem or project given the team-use of the different methods and use of multiple methods by teams. It has been used in both the first- and second-year courses and students have learnt to use the different methods. A disadvantage of this approach where teams are using different methods is that although they see the effectiveness of the methods with respect to the number of ideas generated, each student does not practice each method itself given the limited time available in the workshop session. With planning it is likely that this can be overcome. Another disadvantage with the current structure is the teachers are not observing the students, when the student teams create ideas for their project, whereas in the workshop activity the staff can guide the students if they are having difficulty.

There is also the issue around the reluctance of students to contribute ideas when either being observed, or due to evaluation of their ideas by the other team members or due to dominant personalities within the team [17], and staff were unable to record whether the ideas generated by teams using each technique represented an equal contribution by all team members. It might be expected that some methods resulted in more balanced contributions due to this. It is noted that when the course 228.211 was held during a Covid-19 lockdown in early 2020 and the teaching moved on-line the attempt at this workshop activity where all students and staff participated resulted in only 10-20 ideas overall compared to what is seen in class.

ADAPTING THE APPROACH FOR ON-LINE LEARNING

For the first-year course 247.114 Science Sustainability for Engineering and Technology delivery of the course was planned to be blended and consisted of on-line material which introduced the different idea generation techniques and a workshop similar to the one described in the section above. In 2021, the approach to teaching idea generation needed to be adapted for fully on-line delivery due to a Covid-19 lockdown.

When moving this activity on-line, there were a few challenges which were anticipated and when designing the on-line activity these were taken into account. When conducting an in-person activity students can share their ideas by writing them down on paper or post-its. These can then be displayed so the team can view them and continue to build on these ideas. This aspect of allowing everyone to see the ideas is an important aspect of generating ideas in a team.

When facilitating idea generation sessions staff can determine when groups are struggling based on their body language, noise levels and number of ideas they are generating. This is challenging on-line and if staff enter breakout rooms (as used in Zoom) to check on progress it can disrupt the flow of ideas as the students stop to see what the staff member has to say. It would be ideal if staff could check on progress on-line without causing any disruptions.

Some students are naturally creative while others may not be confident in sharing their ideas as they could be seen as *silly*. This challenge also occurs in person, but the on-line environment does allow people to stay anonymous which may actually allow less confident students to have more input into the idea generation process.

In summary, the on-line environment needs to allow students to share their ideas within their groups, allow staff to monitor their progress and be anonymous to encourage everyone to be involved. It was decided to trial the use of Google Docs and that each of the teams would be generating ideas on the same topic. The topic chosen was alternatives to paper shopping bags (used as an example throughout the first-year course). By generating ideas for the same topic, the teams could compare the types and number of ideas generated using different idea generation methods.

A Google Doc template was set up and copies made for each team. In the main Zoom session students were assigned to breakout rooms and links were posted using the chat function for the Google Docs. Students entered the breakout rooms and opened the link. Within the template students were given one idea generation method to try. The methods included brainstorming, SCAMPER and synectics. The first task for the team was to define what their method was and explain any ground rules when using this technique. Students were then bought back to the main meeting room where one person from each team explained their understanding of the method. This was to ensure that there was a clear understanding of their method and to provide an opportunity to ask any questions to clarify what they were being asked to do. Students returned to the breakout rooms and started generating ideas using their assigned method.

For the first-year course the scenario given to students was that they needed to generate ideas for sustainable alternatives to paper shopping bags. Staff were able to view the Google Docs and monitor whether teams were making any progress. If a team struggled to get started or stalled along the way staff could enter the breakout room to assist the team. Staff could also monitor when the teams started to run out of ideas which helped them judge when to finish the session.

At the end of the idea generation session all students returned to the main meeting room and each team shared their screen and reflected on how well their assigned idea generation technique went and the types of ideas they tended to generate.

It was felt that this on-line workshop was very effective and allowed students to interact and generate ideas in a collaborative way and all students participated in the activity. Staff were able to monitor progress and offer assistance when needed. However, the exercise was not as effective as the in-person version as the atmosphere for an in-person event like this could not be completely replicated on-line.

CONCLUSIONS

A successful module has been developed which uses blended learning to introduce students to a range of idea generation techniques. This approach consists of on-line pre-workshop content which provides an overview of the techniques and then an in-person workshop where groups of students are able to apply different idea generation techniques and discuss their experiences. Once the teams had experienced the techniques in the workshop, they were able to apply them within their project and the teams which used multiple techniques generated more ideas. It is, however, difficult to conclude whether more ideas resulted in higher quality ideas.

Due to Covid-19 lockdown an on-line workshop was developed to replace the in-person activity. This workshop was conducted using breakout rooms on Zoom and utilised Google Docs to allow students to share ideas in a safe environment and staff to monitor progress. While the on-line workshop was successful at allowing students to experience using idea generation techniques and all attendees did participate, the atmosphere created during the in-person workshop could not be replicated on-line.

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