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Making the Abstract Concrete: A Project-Based Laboratory Activity on Concrete Manufacturing for Civil Engineering Students*

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We explored whether a project-based approach and experiential-learning activity would improve learning of complex concepts related to concrete manufacturing in the workplace. We designed a group-based laboratory activity, followed by student-peer teaching and marking and a final report writing task, based on the job of a concrete technician/engineer in a concrete production plant. An action research approach was used to assess student satisfaction (N = 269), their perception of the learning experience, and the impact on their grades. There were four data sources: Observations made by lecturers and TAs, standardised student evaluations, a targeted survey, and course grades. We correlated measures of student peer-teaching with academic output.

Students were satisfied overall with the activity and their perceptions of experiential-learning were positive. The student peer-teaching activity needs improvements. Despite extra online-learning resources provided to compensate for Covid disruptions, students were more satisfied with the in-person activity than with the on-line counterpart. Our positive results suggest that student learning about concrete manufacturing improves when complex theory is integrated with practical learning activities using a project-based approach. We will further modify and integrate learning activities based on these results in our new multi-disciplinary learning spaces.

Keywords: active learning; project-based learning; problem-based learning; peer-learning; peer-teaching; experiential learning; laboratory learning; Covid disruption; concrete manufacturing; student feedback; student survey

1. Introduction

Civil and structural engineers design and oversee construction and maintenance (and potential renovations, repairs and strengthening) of buildings and infrastructure. Engineers must not only master physics and mathematics, but also practical skills related to, for example constructability of the designed structure and code/law compliance such as the New Zealand Building Code and various construction standards (e.g., [1–3]. Concrete is the most commonly used building material in the world [4]. It is therefore imperative that engineering students learn the properties of concrete, how to manufacture and build concrete to the desired result in compliance with the construction codes and laws.

We were concerned about the limited learning outcomes we observed of using traditional teaching approaches to this topic. With calls for more student-centred, active learning opportunities and authentic assessment in contemporary engineering education programmes internationally [5], and substantial support for innovative teaching in the Faculty of Engineering at the University of Auckland, we introduced a new laboratory exercise for civil engineering students based on these principles. This paper reports on the research that we undertook to (a) inform the design of a new laboratory exercise on concrete, and (b) to assess student learning and attitudes to the new learning activities.

1.1 Concrete in Engineering and Construction

Concrete, with the main constituent materials being sand, coarse aggregates, cement and water, is the most commonly used material in the world after water, at 1 m^3 per person per year [4]. The popularity of concrete is mainly due to the low price and versatility, which results in concrete being used in almost any construction project from roads, bridges and other large infrastructure to residential, commercial or industrial buildings of any scale. Even when most of the structure is made of other materials such as steel or timber, concrete is still needed for certain elements such as the foundations. Engineering students must learn how individual ingredients of concrete affect its fresh and hardened properties.

Concrete is a complex material that is often heterogenous and inconsistent not only from country to country but also from region to region and often within the same region. Different types and ratios of aggregates can have a significant influence on the fresh and hardened properties of concrete. Similarly, the type of binder (typically cement) and ratio of binder to water play a vital role on the concrete properties. The inclusion of chemicals or artificial aggregates or other types of binder can further increase the complexity of the concrete. All of these variables will have an effect on the rheology of the concrete (the scientific study of the deformation and flow of fresh concrete), and on the mechan-

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ical properties and fracture mechanics of hardened properties. These concepts are difficult to understand without a hands-on experience, especially of how aggregates and the binder to water ratio affects the rheology of fresh concrete (the viscosity and fluidity of the materials).

1.2 Teaching about Concrete: Active Learning Techniques

Traditional, teacher-centred teaching practices that promote passive learning are not effective tools for teaching these concepts where the texture, the feeling and the detailed observation of physical and mechanical phenomena are difficult to explain without experiencing them [6]. Traditional teaching methods have been proved to be ineffective, especially when dealing with real world problems, because they emphasise memorising of facts, and surface learning [7], rather than understanding of the underlying theories or reasons behind the facts [8–10]. Teaching to promote active learning, where student learning is the central focus of the teaching, better facilitates students' deep understanding of these complex concepts, especially when applied to a laboratory environment [11–13]. Active learning is demonstrated when the student is actively, rather than passively engaged in the learning process [14, 15]. Multiple active learning techniques have been developed over the years, such as problem-based learning, project-based learning, case-based teaching and discovery learning, among others [16]. Active learning requires the student to take ownership of the learning activity [17]. When engaged in active learning, the student adopts a deeper thought process than passively listening to a lecture, a recording or reading a coursebook. Such passive learning behaviours may result in students memorizing information as a recipe, or taking a formulaic approach to learning rather than understanding the underlying concepts [18, 19]. In this research, we used a project-based approach with experiential learning activities for students to learn not only the behaviour of fresh and hardened concrete and the influence of each individual ingredient on the final mix, but also how these properties are assessed in the real world, where the tight quality control required for construction projects is upheld by codes and standards.

Project-based learning facilitates learning that is centred on projects that represent real-life situations [20, 21]. Project-based activities must present a variety of problems that the students need to solve over a relatively long period of time, rather than the typical 1 or 2 weeks that traditional assignments take [22]. This extended period of time is necessary because, while students learn by doing, they also need enough time to reflect on what they have learned [23]. Experiential learning also requires students to reflect on what they have learned during the activity, apply it to close-to-real life situations, and then apply that experience to their learning [24]. We designed the laboratory activity on the premises that it: (1) be based on a project representative of a real-life situation (what a quality control technician working for a concrete production company might be doing), (2) give the students a variety of problems to solve over an extended period of time, and (3) requires students to reflect on what they learned during the laboratory activity and explain it to their peers before preparing a report.

It is widely acknowledged that the best way to learn something is to teach it, and that for a student "*to teach another student may be a particularly effective way to increase content mastery*" [25]. Peer-to-peer teaching and learning is based on this premise; that students share their learning and teach one another in a partnership; either within the same cohort or across senior and junior cohorts where more advanced students mentor junior students [26]. In New Zealand classrooms such peer-to-peer teaching resembles the Māori principle of 'ako', or learning together, but with a slight difference: In a reciprocal learning relationship, the teacher sometimes becomes the learner, and the learner the teacher. In particular, 'ako' suggests that each member of the classroom or learning setting brings knowledge with them from which all are able to learn [27]. Creating the opportunity in the lab for students to teach their peers about their particular lab experiment acknowledged each student's learning process as a valuable contribution to their peers' and to their teacher's learning, while also giving students the powerful experience of having to make sense of their new knowledge in order to teach their peers and their teacher.

A comprehensive literature review of peer-to-peer teaching by Stigmar [28] revealed that the involvement of the students in peer-to-peer activities resulted in improved critical thinking and problem solving, wider student participation and engagement, enhanced social and self-awareness, higher motivation, improved collaborative and communicative skills and a lower dropout rate. These improvements have also been reported by other authors [29]. However, Stigmar's review also highlighted many conflicting studies on whether the use of peer-to-peer techniques resulted on the improvement of academic outputs (grades) or the learning experience (deep learning). With this in mind, we designed the peer-to-peer teaching and learning activities to enhance the learning experience for our students. The peer-to-peer teaching and learning activity was used to bring together the group, foster collaboration and social/personal skills and improve engagement. We investigated what the perception of the students was of their own learning, based on the peer-to-peer activity. This was informed by previously published research on the topic [30, 31].

To conclude, we designed the new activity in the laboratory to improve our teaching of the properties of fresh and hardened concrete, based on the recognised benefits of project-based learning and experiential (reflective) learning, using peer-to-peer teaching to promote a deeper learning experience and to foster group belonging. This initiative is aligned with the University of Auckland's and the Faculty of Engineering's goals of using innovative engineering education approaches, based on research-informed international trends [32, 33].

2. Research Approach

Our main research questions were:

1. How satisfied are students with the learning experience?
2. What were the students' perceptions of their learning experience, and
3. How do students' grades compare to (a) other concrete assessment tools, (b) other course modules, and (c) their overall course grades.

The laboratory activity was interrupted approximately mid-way through by a Covid19-related quarantine, as explained below. So in addition to these three research questions, we also describe and reflect on how this quarantine affected the students' performance and their perception on the in-person and on-line labs.

We addressed our research questions using a mixed methods, action research approach. Action research, being situational and participatory, is concerned with diagnosing and addressing specific issues in the context in which they occur [34]. Researchers and practitioners collaborate on the research, where there is constant interplay between research and practice in cycles of planning, acting, observing, reflecting on and re-planning teaching practice [35]. The ultimate objective is to improve teaching practice [34]. The first author is the lecturer on the course who designed the new lab and conducted the research on its effectiveness, in collaboration with the teaching team and engineering educators in the Faculty. As typically occurs in action research, a combination of qualitative and quantitative research methods was used to address the research questions. These comprised a summative course and teacher survey, a targeted survey specifically on the new lab, observations of student learning behaviours and an analysis of the course grades, as shown in Table 1.

Table 1. Research questions and related research methods

Research question	Research methods
1. How satisfied are students with the learning experience?	Summative course and teacher survey. Student observations.
2. What were the students' perceptions of their learning experience?	Targeted survey specifically on the new lab. Student observations.
3. How do students' grades compare to (a) concrete assessment tools, (b) other course modules, and (c) their overall course grades.	Analysis of the course grades.

To provide the necessary context for the research methods and results, we first describe the engineering course and its background in more detail.

3. Background to the Course

The course is a second-year materials course within the civil and environmental engineering department. It is divided into three modules, concrete, structural steel, and engineered timber. Only the concrete module is discussed here.

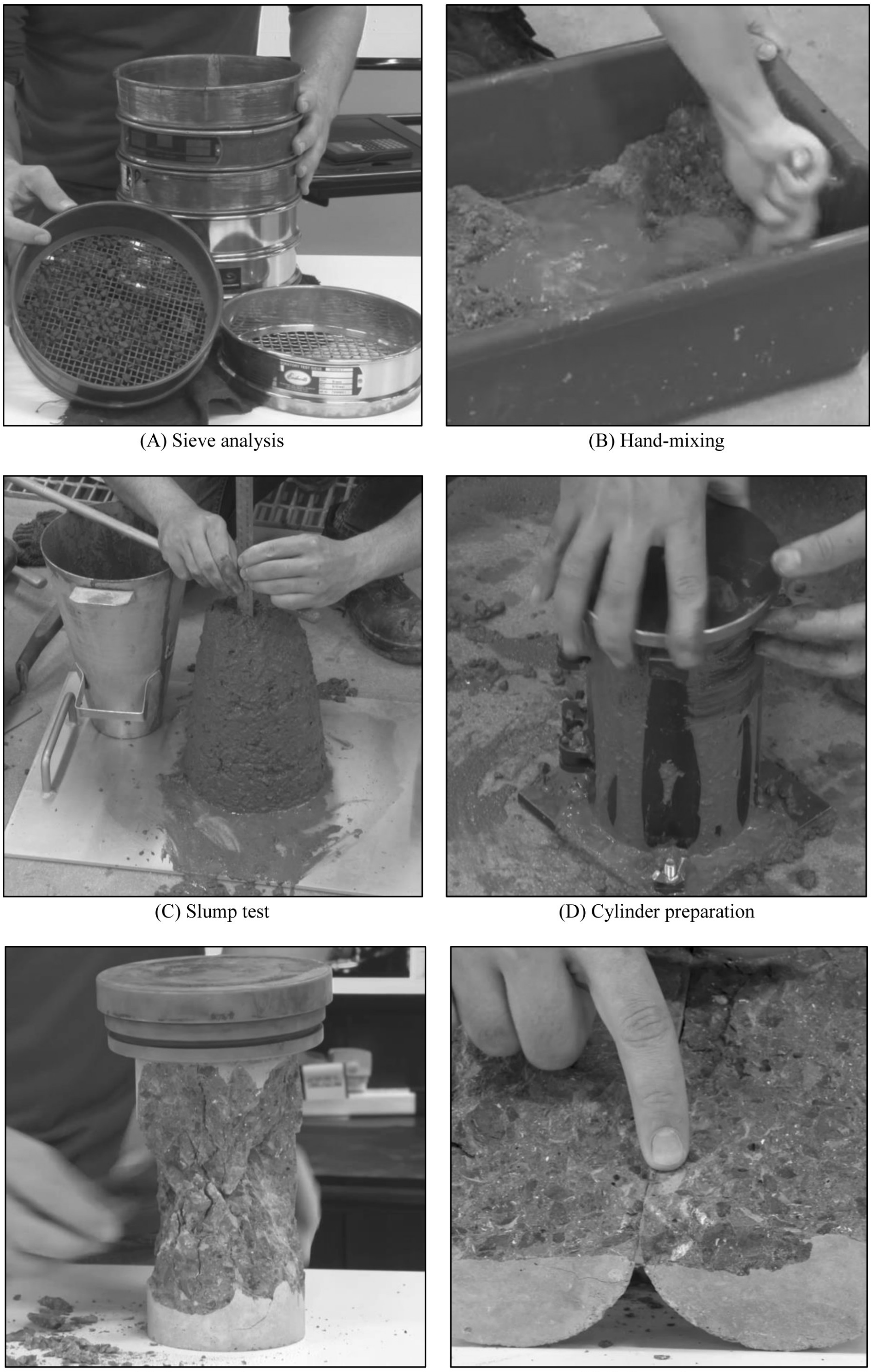
3.1 Previous Years

The course content was delivered in a didactic mode up until 2020, with the lecturers explaining the concepts in a classroom and recording the lectures. Additional reading material and videos were also provided, but we did not provide any opportunities for active learning. The assessment consisted of invigilated tests and a final exam. The course has always received good student feedback, but this is possibly due to the ease of the course. Students could get good grades for relatively little effort. Anecdotal evidence from talking with students in subsequent years suggests that the knowledge they gained was short-lived, a result of shallow learning.

3.2 The New Laboratory Activity

The new laboratory exercise with related changes to the course delivery and assessment was implemented in 2020. A total of 269 students were enrolled in the course, 7 of them based overseas and taking the course completely online. Online quizzes were introduced as a formative assessment for a total of 15% of the total grade (5% per module), and the teachers gave feedback to the students both online and during the lectures (some of which were online because of the Covid lockdown). Another type of formative assessment was included, totalling 30% of the grades (10% per module). The assessment consisted of a design-oriented individual assignment in the timber and steel modules, and a laboratory-based groupwork assignment in the concrete module. This new laboratory assignment, the 'concrete lab', is the focus of this paper. The assignment was divided into three main stages, (1) the laboratory activity, (2) a peer teaching activity, and (3) the report writing and peer-marking.

The laboratory activity consisted of 6 experiments as shown in Fig. 1, (A) Sieve analysis and moisture content, (B) hand-mixing of concrete, (C) Slump test, (D) Cylinder preparation, (E) Compression test, and (F) Split tension test. The cohort was divided into six groups, one group per experiment.



(A) Sieve analysis
(B) Hand-mixing
(C) Slump test
(D) Cylinder preparation
(E) Compression test
(F) Split tension test

Fig. 1. Pictures of the 6 experiments completed in the laboratory activity.

The experiments were designed to help the students understand concepts related to the properties of fresh concrete and the fracture mechanics of hardened concrete, as described in the introduction. Students engaged with the two-hour lab activity in groups. Some groups had 5 students, in which case experiment D was discarded form the assignment. Two Teaching Assistants (TAs) helped the lecturer (first author) facilitate the laboratory activity.

We designed the groupwork part of the laboratory activity so that each student would be responsible of one of the six experiments. This included explaining the method and results to the other students in their group. There was overlap and most students participated in more than one experiment. For example, experiments E and F were run by the first author simultaneously for the students in both groups that were allocated to these experiments. The groupwork was designed with the intention that it would foster peer learning and teaching during the laboratory activity, not only between students within the same group but also between students of different groups. The teaching assistants needed some coaching about when to intervene (e.g., if there was a mistake or an inaccuracy being discussed), and when to let interactions play out by themselves.

One of the motivations for this research was to investigate how students would engage with the lab activity and how much they perceived that it helped them learn. About half of the students could not complete the laboratory activity in person due to a Covid-related lockdown. Insight on the effects of the lockdown on students' uptake of the peer-teaching activity is further discussed below.

The peer teaching activity followed the laboratory activity. The students were instructed to meet together for a discussion, so that each student could explain their own part of the experiment to the group. It was intended that this would improve everyone's understanding of the experiment, as well as the quality of the final report.

The report writing consisted of one group report containing 6 sections, one for each experiment. The objective of the report was not for the students to describe what had been done in the laboratory and do some calculations, but to assess if the lecturers and TAs had done everything in accordance with the industry standard. In other words, the students were immersed into the work that concrete technicians and concrete engineers do in concrete production plants, and their task was to evaluate or audit whether the laboratory activity complied with the industry standards. Thus, the activity had a clear project-based component where the students were replicating a close-to-real-life situation. The report was worth 7% and all students in a group would get the same grade. Peer marking was organised to account for the other 3% and provide an individual grade to each student. The peer marking was mandatory. Each student was asked to mark their group peers on a scale from 1 to 10 for their contribution to (1) the laboratory activity, the (2) peer-teaching discussion, and (3) the final report writing. It was clearly explained that they were not supposed to give high or full marks to all the students in the group. The objective of the peer marking was clearly explained in class and on the peer marking form itself. The students were also told that they would be penalised if they gave everyone in their group the highest mark, but this is precisely what happened. This is discussed in more detailed below.

When the course was disrupted by Covid-related restrictions to on-campus activities, a little over half of the groups had completed the laboratory activity, i.e. 26 of the 44 groups (59%). None of the other groups (18 or 41%) could complete this activity in person. The first author made a recording of all the labs and uploaded it for students to access it. The peer-teaching activity could still be completed on zoom. Unintentionally, we could study the difference between in-person and online teaching/learning, as discussed below.

4. Research Methods

Our three research questions (RQ s) directed the selection of research methods (see Table 1). Three main research tools were used: (1) standardised student satisfaction evaluations, (2) a targeted survey created by the authors, and (3) the grades from the other sections in the course. The satisfaction evaluations are designed to measure the students' satisfaction, while the survey questions were formulated to understand how the students perceived that the laboratory activity and subsequent assignment helped them in their learning experience. Naturally, it is not always possible to separate students' perception of learning and their satisfaction about their learning experience. Their answers to the student satisfaction survey will be at least partially influenced by their perception of how the laboratory activity helped or hindered their learning experience, and their answers about their perception of their learning (in the targeted survey) will be influenced by their satisfaction with the learning activities. For example, in question 5 of the targeted survey, where they were asked how important they thought the lab activity was for their learning. This is discussed in more detail below. Nevertheless, all questions from the targeted survey were used to answer Research Question 2. All the answers relevant to the concrete module were collated and are reported in the APPENDIX. Selected responses are quoted or paraphrased here.

4.1 RQ 1 – Student Satisfaction through Summative Evaluations

The University of Auckland conducts summative evaluations of courses and teachers at the end of each semester, called Student Evaluation of Teaching, or SET surveys. These centralised student feedback systems contain a series of pre-determined questions (by the university's central administration) which students answer using a 5-point Likert scale (from strongly disagree to strongly agree). There are also two open-ended questions: "What was most helpful for your learning?" and "What improvement(s) would you like to see?". The responses to the course feedback were not very helpful as regards the new laboratory, as the students gave broad feedback about the course. This is a common and anticipated limitation when such standardised surveys are used for summative course evaluation in higher education [36].

4.2 RQ 2 – Student Perception of the Learning Experience with a Targeted Survey

We conducted a targeted survey using a popular cloud-based surveying tool. The survey was administered directly after the lab activity and student reporting was finished so that students had a fresh memory of their experience. Each student was asked if they had completed their laboratory in person or online. The survey consisted of three questions with the students responding to a number of statements on a 5-point Likert scale of agreement to disagreement. A final open-ended question was intended to assess how useful the students perceived the laboratory activity and related activities to be: "*Do you want to add something or give any recommendation about the concrete teaching laboratory and lectures for future years?*". The data was quantified and normalised by giving a score of 1 to 5 and calculating a percentage. In other words, if all 60 respondents answered Strongly Agree (5 points) that question would get 300 points, or 100%.

4.3 RQ 3 – Impact of the Lab Activity on Grades through Grade Analysis

The grades for the concrete module were collected for each of the three marked sections – the report on the concrete laboratory, the peer marking and the online quizzes. Similarly, the grades for the other two modules on steel and timber were collected together with the grades from the exam and the final, overall course grade. The results were collated and compared.

5. Results of the Study

The results of the study are reported in response to each of the three research questions.

5.1 RQ 1: How Satisfied are Students with the Learning Experience?

The majority of the feedback was positive, with common responses being variants of "*The concrete laboratory was a good experience as we got to get real world experience*" or "*it* [the lab activity] *gave valuable insight into the material we were studying*". The responses to the teacher evaluation part of the SET survey were more useful, not only for the lecturer to improve his teaching and delivery in future years but also to understand what the students liked and didn't like. The majority of the comments to what was useful for their learning were broad (e.g., "*the concrete laboratory was a good hands–on experience*"). Generally speaking, students found the lab activity and the reporting challenging but very rewarding because they thought it was similar to what they were going to be asked to in their future work as engineers.

5.1.1 SET Survey Results

The SET surveys are divided in two, the first SET results for the course are reported in Table 2 and the second SET results for the teacher are reported in Table 3. For the course feedback, the average of mean scores was about 3.9 for all the questions, being highest for how the assessments supported the aims of the course and lowest on how useful the feedback was to students during the course. This reflects a common trend in SET scores across Faculties, where students often rate the usefulness of course feedback the lowest compared to the other course attributes (listed in Table 2). We were encouraged by this positive result, where almost 75% of the students agreed or strongly agreed with the statements in the survey. The average of mean scores for the teacher feedback was higher at 4.26, and the percentage of students agreeing or strongly agreeing with the statements was also higher at 86%. The SET responses also revealed areas where the lecturer could improve teaching methods and inspire the students to learn more.

5.1.2 Logistical Difficulties

The majority of the suggestions for improvement were related to organisational issues. The students complained that there was no alternative plan for when the city of Auckland went into Covid lockdown, while other courses had recorded their labs in advance: "*I feel that after the semester one lock down, labs should have been ready to go online*

Table 2. Quantitative feedback from the SET evaluations – Course specific

Question	Mean	SD	D	N	A	SA	NA
The course content was well organised	3.96	0.0%	5.7%	18.9%	49.1%	26.4%	0.0%
The aims of this course were clear to me	3.98	0.0%	9.4%	7.5%	58.5%	24.5%	0.0%
The resources (including digital resources) in this course helped me to learn	3.94	0.0%	5.7%	17.0%	54.7%	22.6%	0.0%
I was clearly informed how my learning would be assessed	4.13	0.0%	9.4%	9.4%	39.6%	41.5%	0.0%
Assessments supported the aims of this course	4.25	0.0%	3.8%	7.5%	47.2%	39.6%	1.9%
I received helpful feedback on my learning progress	3.58	1.9%	13.2%	28.3%	37.7%	18.9%	0.0%
I found this course intellectually stimulating	3.85	0.0%	11.3%	15.1%	50.9%	22.6%	0.0%
This course helped me to develop my thinking skills (eg, framing an enquiry, critical analysis, problem-solving)	3.68	0.0%	13.2%	20.8%	50.9%	15.1%	0.0%
I was satisfied with the quality of the small-group teaching (eg, tutorial, laboratory, seminar) associated with this course	3.87	3.8%	5.7%	17.0%	45.3%	26.4%	1.9%
Overall, I was satisfied with the quality of this course	3.79	0.0%	5.7%	22.6%	58.5%	13.2%	0.0%
Average	3.90	0.6%	8.3%	16.4%	49.2%	25.1%	0.4%

Table 3. Quantitative feedback from the SET evaluations – Teacher specific

Question	**Mean**	**SD**	**D**	**N**	**A**	**SA**	**NA**
The teacher was well prepared for the lectures	4.42	0.0%	0.0%	5.8%	46.2%	48.1%	0.0%
The objectives of the lectures were clearly explained	4.35	0.0%	1.9%	9.6%	40.4%	48.1%	0.0%
The teacher explained concepts and answered questions in ways that I can understand	4.21	1.9%	1.9%	13.5%	38.5%	44.2%	0.0%
The teacher used learning resources (including digital resources) in ways that supported my learning	4.25	0.0%	3.9%	7.8%	47.1%	41.2%	0.0%
I found the teacher approachable	4.25	3.8%	3.8%	9.6%	28.8%	53.8%	1.9%
The teacher inspired me to learn	4.04	3.8%	5.8%	11.5%	40.4%	38.5%	0.0%
Overall, the teacher was an effective teacher	4.28	0.0%	3.8%	9.4%	41.5%	45.3%	0.0%
Average	4.26	1.4%	3.0%	9.6%	40.4%	45.6%	0.3%

straight away, or at least within a couple of weeks" and "*He should have had more foresight with regards to the concrete laboratory being postponed due to the lockdown (all our other labs had online versions prepared)*". Unfortunately, the media recording team within the University was not available to record the laboratory before the city went into lockdown because of the large number of courses going through the same problems, but the students were not aware of this situation. There were also a couple of comments regarding the clarity of the instructions for the report, e.g., "*Provide more clarifications on the laboratory report*" and "*Concrete laboratory and report were confusing*".

Most students were satisfied with the online resources used in the course despite the problems with the Covid lockdown and the delays on the laboratory activity. The lecturers provided additional resources to support their learning, such as online office hours, extra worked examples, and more exam template questions than in previous years.

5.2 RQ 2: What were the Students' Perceptions of their Learning Experience?

5.2.1 Students' Perceptions of the Teamwork and Peer Teaching

The first author and the Teaching Assistants observed the students' behaviour during the laboratory activities. The students engaged actively in peer teaching and discussion, with the flow of teaching often changing in direction to and from students and teachers. It was encouraging to observe this spontaneous enactment of 'ako', with the reciprocal exchange of learning and teaching between teachers and students. However, many students highlighted how the laboratory activity only helped them to learn the experiment that they were in charge of, for example "*it* [the lab activity] *only really helped me understand the concepts involved in my specific experiments*", "*I can remember well the experiments that I did but don't remember well those that the other group did*" and "*It was quite easy to only focus on your section of the laboratory and laboratory report. So I felt I* *only found the laboratory benefits last for the specific task I physically did.*".

We think that most of the students understood the purpose of the laboratory, that each student was to focus on one experiment and then they were supposed to explain to each other the other experiments. However, this discussion and peer-teaching part of the lab activity was not organised or facilitated in any way. We under-estimated how much guidance and instruction students needed to do this by themselves. The students felt, and we agree, that this was not adequately implemented in practice. Two students went as far as to acknowledge that the idea was good but it didn't work in practice: "*Putting responsibility on the students to teach the subjects is interesting. In theory they should teach it, but in reality it isn't necessary for maximum grades which is what a student is concerned about. Understandably each member can only do 1 part of the laboratory in the allotted time, however I did not learn much about the other tests from my members*". This last comment also highlights the excessive importance that students give to grades, which has also been echoed by other comments, e.g., "*Pretty disappointing having to rely most of your grade on the work other people do without much say on your behalf*".

5.2.2 Students' Perceptions of the Lab Activity

The targeted survey gave us insight on students' perceptions of how useful the laboratory activity and related components (peer teaching and report) were in their opinion. It gave much better insight into the students' opinions of the laboratory than the SET survey results. Out of 262 potential candidates, 60 (22.9%) replied to the survey. Of those 60, 35 gave written answers to the open-ended questions as well as responding to the Likert scale questions (58.3% of the 60 or 13.4% of the 262). All the answers are reported in the APPENDIX.

All students accepted the informed consent question (Question 1). Question 2 informed us whether the students completed the laboratory in person (43/60. 71.7%) or online (17/60, 28.3%). The percentage of students that answered each statement is reported in Table 4 for question 3 and Table 5 for question 4. A graphic summary has been prepared in Fig. 2 for question 3 and in Fig. 3 for question 4. A summary of the responses to question 5 is reported in Fig. 4.

Responses to Question 3: To what degree do you agree with the following statement "The experience in the concrete teaching laboratory (or video) helped me understand the following concepts better"

Table 4. Responses to Question 3: "The experience in the concrete teaching laboratory (or video) helped me understand the following concepts better"

Concept	SD	D	N	A	SA
1. Concrete aggregates	0.0%	1.7%	10.0%	40.0%	48.3%
2. Absorption and moisture content	0.0%	8.3%	13.3%	46.7%	31.7%
3. Concrete mixing	0.0%	10.0%	6.7%	35.0%	48.3%
4. Concrete fresh properties	1.7%	10.2%	11.9%	32.2%	44.1%
5. Concrete hardened properties	1.7%	13.3%	18.3%	33.3%	33.3%
6. Concrete fracture and failure	5.0%	15.0%	11.7%	35.0%	33.3%
Average	1.4%	10.0%	12.0%	32.0%	39.6%

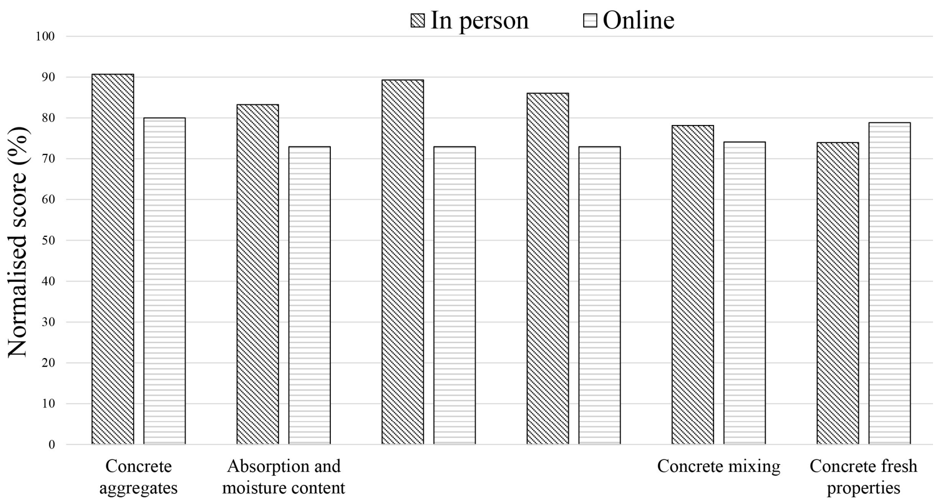


Fig. 2. Normalised score for each concept of Question 3 of the survey, separating online and in person experience.

Concepts 1, 3 and 4 received the highest 'agree' and 'strongly agree' responses. We think that the reason for this was the extra benefit students had of learning these concepts in person as opposed to remotely, using books and videos. For example, it is easier to understand the difference between stiff concrete and more liquid concrete when you mix it by hand.

The concrete fracture and failure (Concept 6) received quite a lot of 'strongly disagree' and 'disagree' responses. These are the most complex topics in the whole concrete module. The students did not perform this test themselves but rather observed the lecturer doing it and explaining what was happening. Again, the benefits of completing this task in person outweigh reading about it in books or watching videos. This observation is corroborated in Fig. 2, with the largest difference between in person and online satisfaction being for concepts 1, 3 and 4 and the satisfaction being reversed for concept 6 (more satisfaction with online teaching than in person).

We are not sure why the satisfaction level reversed for concept 6. We speculate that it was because the recording was provided after students had participated in several labs, and the lecturer had improved his teaching of those concepts. Additionally, having the recording allowed the students to pause the video and re watch it as many times as needed. All students had access to this recording, not only those students who completed the laboratory activity online.

Responses to Question 4: To what degree you agree with the following statements?

The peer-teaching presentation/workshop received lower scores than the laboratory activity or the report writing, as shown in Table 5. The trend of positive perceptions of learning by the in-person students can be seen in Fig. 3 with lower scores for the peer-teaching activities. Nevertheless, the high percentage, on average, of agreement scores for all three statements in the survey (Table 5) reflects that in general, the concrete lab activity is an effective learning exercise with aspects that require further improvement, particularly the peer teaching component.

Responses to Question 5: With which of the following statements do you agree?

This question was intended to provide insights on students' perceptions of the usefulness of the laboratory activity for their learning. We expect the answers to this question to be heavily influenced

Table 5. Responses to statements in Question 4

Concept	SD	D	N	A	SA
The experience in the concrete teaching (or video) was useful to learn the concepts better	1.7%	1.7%	3.3%	38.3%	51.7%
Preparing and presenting the results to my peers was useful to learn the concepts better	3.3%	11.7%	23.3%	33.3%	26.7%
Writing my section of the laboratory report was useful to learn the concepts better	0.0%	8.3%	6.7%	35.0%	50.0%
Average	1.7%	7.2%	11.1%	35.6%	42.8%

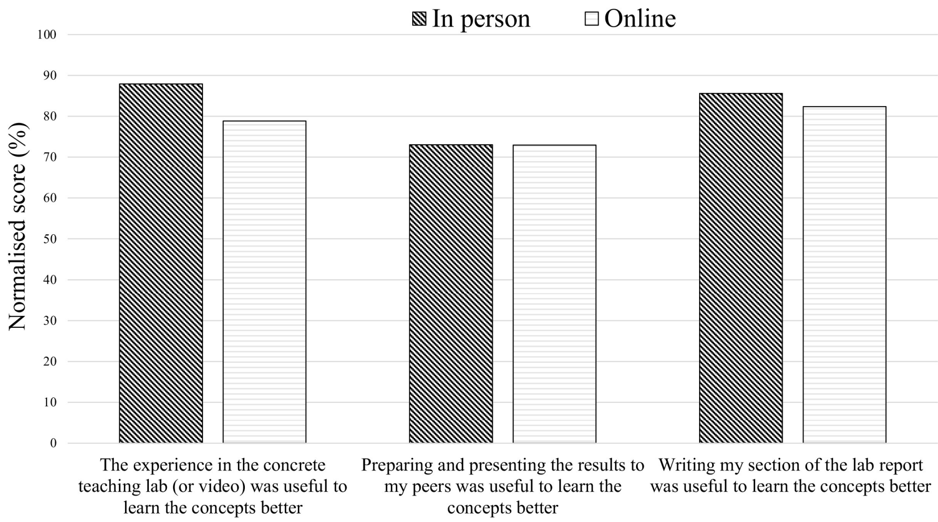


Fig. 3. Normalised score for each concept of Question 4 of the survey, separating online and in person experiences.

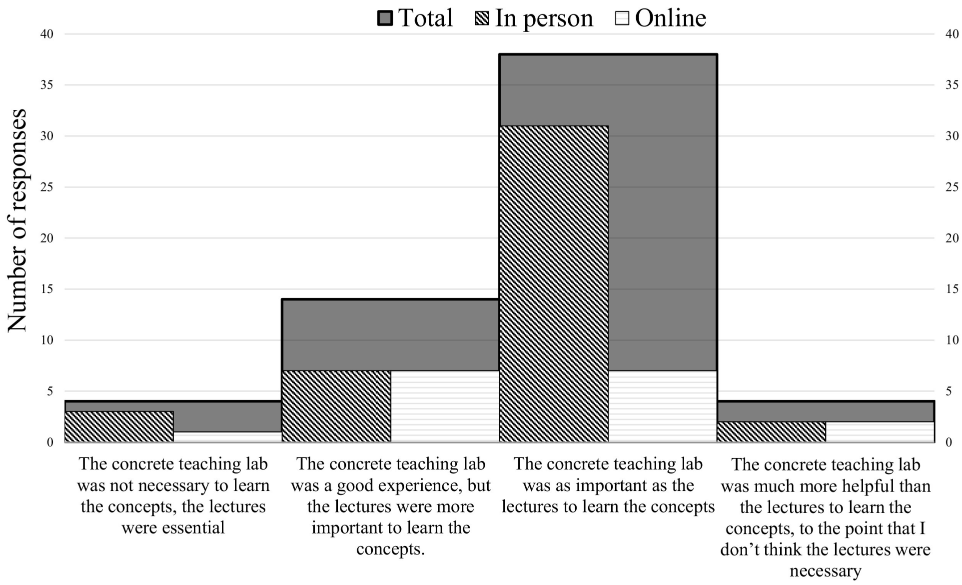


Fig. 4. Summary of the responses to Question 5 of the survey.

by the students' satisfaction with the lab activity, so this question provides answers to both RQ1 and RQ2. For the sake of simplicity, we report these results here.

The vast majority of students thought that the laboratory learning experience was as important as the lectures, overwhelmingly so for those students who completed the laboratory in person (inclined pattern in Fig. 4). We are considering moving away from the lectures altogether and teaching these concepts only in the laboratory in future. Such a change needs further research-informed course re-design, and it must be practically feasible within the logistical constraints of the teaching spaces, time and resources available. We elaborate on this later in the Discussion.

5.2.3 Analysis of Students' Responses about Peer Marking

The main objective of the peer marking was to calibrate the grades of the group assignment for the students' benefit so not every student would have the same marks if they contributed differently to the group project. This was explained to the students several times – they were not supposed to give everyone the same grades and certainly not a 10 to everyone. The teacher told them that if they think they all deserved the same mark then they all should give each other between 6 and 8, and reserve 9 and 10 for those students that went the extra mile. Similarly, they should have reserved the 1 to 4 for the students that did not do enough. For the assignment, three questions were asked about the peer marking, each worth 1% of the final grade. The questions and a brief explanation to each question are included below. A histogram of the grades awarded to each student for all three questions is reported in Fig. 5. The trends in students' responses was similar in all three questions.

Question 1: How would you rate the team member's contribution to the laboratory activity*? The answer is from 1, where the team member did not attend the laboratory, to 10, where the team member did more than what it was required of them. If your group did not complete the in-person laboratory give 0 to everyone.*

Question 2: How would you rate the member's contribution to the peer-teaching discussion and/or presentation*? The answer is from 1, where the team member did not contribute to the discussion and/or presentation, to 10, where the team member did more than what it was required of them. If your group did not complete the discussion/presentation, give 0 to everyone.*

Question 3: How would you rate the team member's contribution to the report*? The answer is from 1, where the team member did not contribute to the report, to 10, where the team member did more than what it was required of them. Give a 0 only to students that have not completed their part of the report.*

It is important to note that for a student to get 0 or 10 all the students in their group had to give 0 or 10 respectively. It seems that about 18 students (3 groups) got 0, but in reality 18 groups (41%) didn't complete the laboratory in person. If the students had done the peer-review correctly, 18 groups should have received 0, as this indicated that they didn't complete the laboratory in person. Additionally, the majority of the students got 100%, but the students were only supposed to give 100% to those that went the extra mile. These two examples indicate that most of the students did not read the instructions carefully. One potential reason is because all the assignments were lumped at the end of the semester after the delays caused by Covid. A potential solution to this could be to limit the number of high grades that they can give, for example only one 10 and two 9s. Another solution would be to request a qualitative rather than a quantitative measure, formulating the scale by providing verbal descriptions for students to rate their (dis)agreement with, rather than having students assign a score (for example, 'the student didn't contribute enough', 'the student contributed what was expected of him/her', 'the student contributed more than what was expected of him/her'). It is important to note that the peer marking took place a long time after the activity due to the Covid-related lockdown. The validity of the peer marking would be improved if the students had made these judgements shortly after the lab activity.

A detailed analysis of the data and discussions with several groups revealed that at least 6 of the 26 (23.1%) in-person groups and 9 of the 18 (50%) online groups did not complete the peer-teaching tasks. Clearly being in a lockdown environment disincentivized group engagement, but other solutions need to be implemented in the future to foster group collaboration and peer teaching/learning. We suggest two options, (1) to organize multi-use rooms with screens and large tables for the teamwork so that the lecturers and/or TAs can provide explicit coaching and support for the peer teaching, and/or (2) to attach deliverables and marks to the peer-teaching tasks (which is against our initial philosophy when designing this course).

5.3 RQ 3: How do Students' Grades Compare to (a) other Concrete Assessment Tools, (b) other Course Modules, and (c) their Overall Course Grades

A summary of the grades for each module, the exam, and the final, overall course grade is reported in Fig. 6a. The summary of the grades for each of the components of the concrete module is reported in Fig. 6b. The most obvious observation is that the grades of the exam were lower than for the lab reports and more evenly distributed. This is to be expected, as students have more time to work on the report than they do to finish the exam. In addition to that, there was a lot of Covid-related stress in the days leading up to the exam. All the exams that took place after this exam were moved online. The grade distribution of the lab report is very similar to the

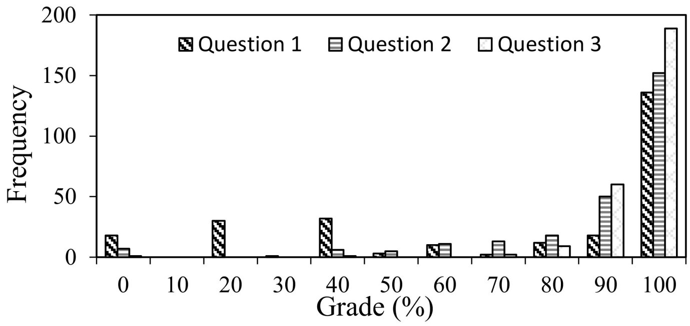
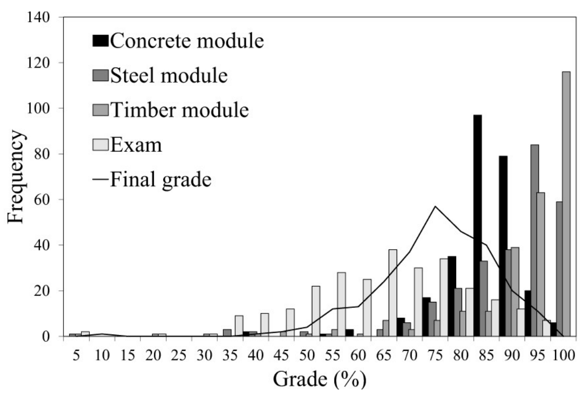
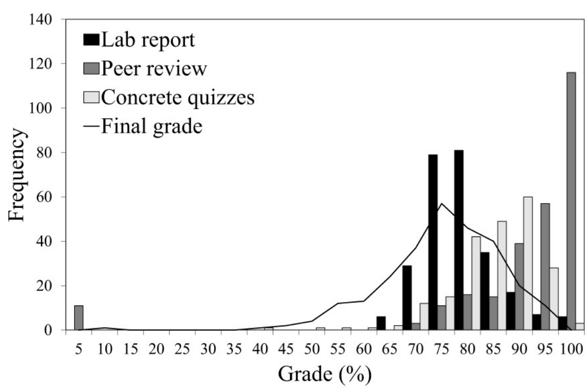


Fig. 5. Histogram of student's grades for the peer marking.



(a) Course grades



(b) Concrete module grade

Fig. 6. Summary of the course grades and concrete module grades.

final grade distribution, suggesting that the lab report grading was an appropriate assessment method. Similarly, the grades for the concrete module and their distribution are much closer to the final course grade than those for the other course modules (Fig. 6b), being a better representation of the general grade (e.g., the timber module had a large number of students scoring in the 95–100 band (120/269 or 44.6%). By contrast, the grade distribution of the peer review is severely skewed towards the high grades, as discussed above, and this assessment method needs to be re-designed.

The grades from the quizzes were a bit higher than those from the report, probably because the students had time to think and find an answer either in the coursebook/lectures or on the internet. The average completion time for the quizzes was 35 to 40 minutes, but the students were given 1 hour to complete them.

6. Discussion

The most critical observations made concerning the new concrete lab activity are discussed in this section.

6.1 Reflection on the use of Project-Based Learning and a Laboratory Activity in Teaching Concrete Production

We have no doubt that the students are better prepared as a result of undertaking the lab activity, where they better learned complex topics related to concrete mixing, aggregates absorption, flowability of concrete, concrete fracture. The format of the assignment also helped them to understand how to read construction standards, quality control of concrete, and the importance of the concrete/site engineer in the construction industry. In this particular aspect, the activity was a resounding success, as reflected by the students' feedback.

We are working towards removing the lectures on this topic altogether and combining the theory with the practical aspects in the teaching of this topic. This would mean that students learn about the rheology of concrete while doing the experiments in the laboratory. Our preliminary thoughts about such a course re-design are that the students do preparatory reading and learning before attending the laboratory, and then undertake carefully integrated practical tasks during that lab to help them consolidate the correct application of the theoretical principles. Based on recent research outcomes of similar course re-designs in other civil and computer engineering courses (e.g., [37], [38]), we are confident that such a flipped classroom approach will further improve this crucial learning process for the students.

6.2 Reflection on Peer-to-Peer Teaching and Team Building

The new activity was highly successful in implementing peer-to-peer teaching within the laboratory, while the activity was on-going. We often observed students taking the lead to teach their peers a particular detail of the experiment, and they became the learners when another experiment was being discussed. This observation clearly reflected the Māori principle of 'ako' as a reciprocal learning relationship. Observations during the laboratory activity indicated that this exercise also promoted team building, student participation and engagement, and improved collaboration, as previously observed by others [28]. Students typically started the activity by being shy and inwards with other members of the team, and slowly opened up to often leave the room as a group of friends exchanging phone numbers and social media details. However, and based on the comments from the students discussed below, these benefits observed in the laboratory either disappeared or were significantly reduced when the activity was finished.

6.3 Reflections on Organisational Issues and the effect of Covid Lockdowns

The laboratory activity was interrupted about halfway through with a Covid-related lockdown. In addition, we could not get a recording by the media team at the University due to the sudden high demand by a large number of other courses for similar requests to record their lab-based activities, even though we made the request weeks before the lockdown started. Nevertheless, better planning should have been in place. This provided us with the unexpected opportunity to observe the students' satisfaction drop when the lockdown happened, with the percentage of students thinking that the concrete lab was as important as the lectures being 4 times higher if they did the lab in person compared to doing it via a recording (Fig. 4).

Similarly, the students that did the lab in person rated their perception on how helpful it was approximately 10% higher than those that completed the activity by a video recording (Fig. 2 and Fig. 3). This finding will be monitored in future iterations of the course and of the lab activity. The peer-to-peer teaching activity needs to be more carefully designed, because leaving it to the students to do peer teaching themselves did not give good results. Two potential options that we propose are: (a) to have common study rooms with hours assigned to each group so they can meet and discuss with lecturers or TAs present to coach them, and (b) to assess this portion of the assignment. Option (a) gives them structured, supported time and space for peer teaching in their groups, while option (b) requires an assessment rubric, which, while making aspects of the required peer teaching more explicit, may also narrow down the possibilities for the students.

6.4 Reflection on Students' Feedback

We can make two main comments from analysing the students' responses. First, there should have been better contingency plans in case of a future lockdown for a smoother transition to on-line learning. Second, the peer-teaching activity needs to be better organised so the students can benefit more from this learning mode and leverage each other's experience. Several options are available to improve this activity. An example could be to organise a room with tables and large screens to share data, images and/or presentations where the lecturers and TAs can provide coaching. Another option could be to add a deliverable where the students need to submit what they presented to their peers and some minutes of the meeting. We think that the first option may result in fewer of the students completing the peer-teaching activity than the second option, but it allows for the original motivation of transferring more responsibility for learning to the students, and empowering them to learn by teaching [39]. Additionally, the second option is much more time-consuming for the teaching team.

7. Conclusions and Recommendations

We designed an experiential laboratory learning activity for students to better learn the concepts of concrete manufacturing, using a project-based approach and peer-to-peer teaching. A Covid lockdown occurred about half-way through the laboratory activity, which unintentionally allowed us to observe the different levels of satisfaction of in-person and on-line students, as well as their perceptions of their learning and their grades. The development of this laboratory activity was aligned with the University's and the Faculty's goals of innovative teaching, as well as national and international trends in engineering education. The data was collected using teachers' and TA's observations, standardised student evaluations, a targeted survey on the activity and the course grades. The results are reported in relation to the Research Questions and our discussion reflects on project-based and experiential learning, student peer-to-peer teaching, the course grades and Covid-related issues. The main conclusions are:

- The laboratory activity was successful in improving the students' learning as well as their perception of learning. Experiential learning helped them learn the complex concepts of concrete production while project-based learning helped them to understand the job of a concrete engineer. The grade distribution of the lab report closely matched that of the final grade, suggesting that it was a fair assessment.
- The peer-to-peer activity did not work as intended, with most students not even completing the activity. This portion of the assessment needs to be carefully re-designed to ensure that the students complete it. We propose to better facilitate the student peer teaching using one of two options, (a) organise the space and time for the peer-to-peer teaching to occur and/or (b) attach grades to the activity.
- The peer-to-peer marking did not work as intended, with most students giving top grades to everyone as reflected by the score distribution. This portion of the assessment needs to be carefully re-designed to ensure that the marking is adequately completed. We propose two options, to (a) limit the number of students that can get a certain mark within each group and/or (b) substitute the numerical scale with statements that students rate their (dis)agreement with.
- The Covid lockdown had a significant negative effect on the team building efforts, as expected. Additionally, the students that completed the activity in-person reported a higher level of satisfaction than their peers who completed it on-line.

To conclude, the results achieved from this first iteration of the project-based laboratory activity are generally satisfactory. The discussion reported here gives us enough confidence on the effectiveness of this method for students to successfully learn the complex concepts related to concrete manufacturing. Future iterations will aim at improving the peer-to-peer teaching and marking, using the existing body of pedagogical research on the topic as a foundation.

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