Back to Experiential Learning in Mechanics of Structures at Swinburne University of Technology

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ABSTRACT

CONTEXT

The return to on-campus delivery of most 1st year subjects in Engineering courses at Universities in Australia in 2022 provided an opportunity for subject co-ordinators to further accentuate the points of positive differentiation of face-to-face delivery over fully online to their students. A form of learning that is particularly recognised as applicable to the more practical fields of study, (such as Engineering), is identified as *Experiential Learning (EL), learning by doing* or *hands-on learning.* Hands-on performance of lesson-focused experiments by students working in pairs, (or solo), is viewed by the authors as providing a deeper EL experience than say Problem Based Learning.

PURPOSE OR GOAL

Attempts in response to feedback from the 2019 Subject Review Survey (SRS) in the1st year subject ENG10003 Mechanics of Structures at Swinburne University of Technology (SUT), that encouraged broadening EL opportunities in the Blended Learning mix adopted for this subject, were severely hampered by COVID19 lockdowns and associated restrictions in 2020 and 2021. A model bridge-building exercise involving individual student hands-on construction and testing was therefore set as a significant staged EL home assignment for ENG10003 during this time. This assignment was retained as a much appreciated and enjoyed EL task into 2022. Additional hands-on EL opportunities to the two formal TechnoLab™ experiments (Warren Truss and Shear and Bending in Beams) were introduced by way of four mini experiments in 2022. These replaced their video experiment counterparts delivered online in this subject in 2020 and 2021. Hands-on performance of these additional experiments was reported by students in the SRS of Semester 1, 2022 as further enhancing their learning experience and satisfaction with delivery of this subject.

APPROACH OR METHODOLOGY/METHODS

It was recognised right from the outset that a definitive measure of the enhancement to learning from hands-on experiments introduced in 2022 in ENG10003, would be impossible, so that less formal anecdotal or opinion-oriented responses from students would need be relied upon.

ACTUAL OR ANTICIPATED OUTCOMES

EL teaching practice is anticipated to continue to be recognised and appreciated by students as enhancing their understanding of key concepts and methods of analysis in statics and mechanics.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

Experiential learning via lesson-focused hands-on experiments performed by students working solo or in pairs, as offered by the TechnoLab™ platform of experiment kits, offers a deep learning opportunity for Engineering students of Statics and Mechanics.

KEYWORDS

Experiential Learning; deep learning; mini experiments; lesson-focussed; hands-on

Introduction

Swinburne University of Technology (SUT) is noted in Australia as arguably the leading university in practice-focused delivery of its engineering courses. Work Integrated Learning (WIL) opportunities with placements in industry over one or two semesters have been offered in the course structure of all sub-disciplines in Engineering for quite some time. In addition, a growing emphasis on other forms of Experiential Learning (EL), such as significant “hands-on” opportunities in the delivery of subject material has been exercised and incorporated within course designs.

Unfortunately, the advent of the recent global Covid19 pandemic saw some major operational restrictions being imposed on universities in Australia. Government mandates necessitated campus lockdowns virtually over the entire academic years of 2020 and 2021 and forced delivery of tertiary level courses to essentially be totally online. Some universities were better placed than others to satisfy this requirement having already developed experience in the delivery of online courses, either in their entirety or partially as a component of a hybrid delivery arrangement.

ENG10003 delivery during 2020-2021 lockdowns

The campus lockdowns affected what otherwise would have been the continuation of the delivery of two hands-on performed experiments by students working in pairs and as noted in the syllabus of the subject ENG10003 Mechanics of Structures at SUT prior to 2020. Students enrolled in the subject during the lockdown periods of 2020 and 2021, instead had these two experiments presented to them online as detailed video-labs.

Students were still required to write-up and submit a formal Laboratory Report as if they performed the experiments themselves, as these report submissions formed part of their assessment for the subject. They needed to analyse and interpret the results from the raw experiment data and incorporate these results and answers to prompted questions in the report pro-forma, individually, as was done by students enrolled in the subject prior to 2020, when these experiments were actually performed by students hands-on, working in pairs.

Introduction of new Experiential Learning initiative

A new EL initiative, prompted by the campus lockdowns, was therefore introduced in ENG10003 for the first time in 2020 by the subject co-ordinator by way of a student “build-and-test-at-home” exercise. (This activity was formulated as a major all-through-the-semester assignment with reports of staged elements of its execution submitted for assessment of overall individual student performance in the subject to the level of 40% of their final grade.)

The “build-and-test-at-home” exercise that was set for Semesters 1 and 2 in 2020 (a variant of which was repeated in 2021) was for a bridge that needed to span a minimum distance of 500 mm and achieve the highest load carrying capacity (load distributed over the deck or acting as a point load at centre-span) to self-weight ratio of the bridge. Quite a bit of “latitude” was afforded to the students in terms of choice of materials to use, the style and form of their bridge design and the manner in which components were to be joined. The use of metal, however, was restricted to connections and not permitted to form part of the main open span of the bridge.

A consequence of the near “open-ended” nature of this assignment saw a very wide spread of build designs produced by students in this subject, as depicted in the collage of examples chosen for display in Figure 1. As can be identified in this figure, timber in the form of thin slats, Balsawood veneer and popsicle sticks proved to be the most popular material choice with spaghetti or cardboard lengths (sticky-taped and/or glued together) and acrylic being less popular in these designs. The physical size of the bridges also varied, and in most cases their main span was significantly longer than the nominated minimum span length specified for their build of 500 mm.

It was clear to the authors, that the socio-economic circumstances at the home base of students in the ENG10003 subject during 2020-2021 (that would include access to materials and a well-equipped workshop) played a significant role in influencing the resultant build for this assignment.

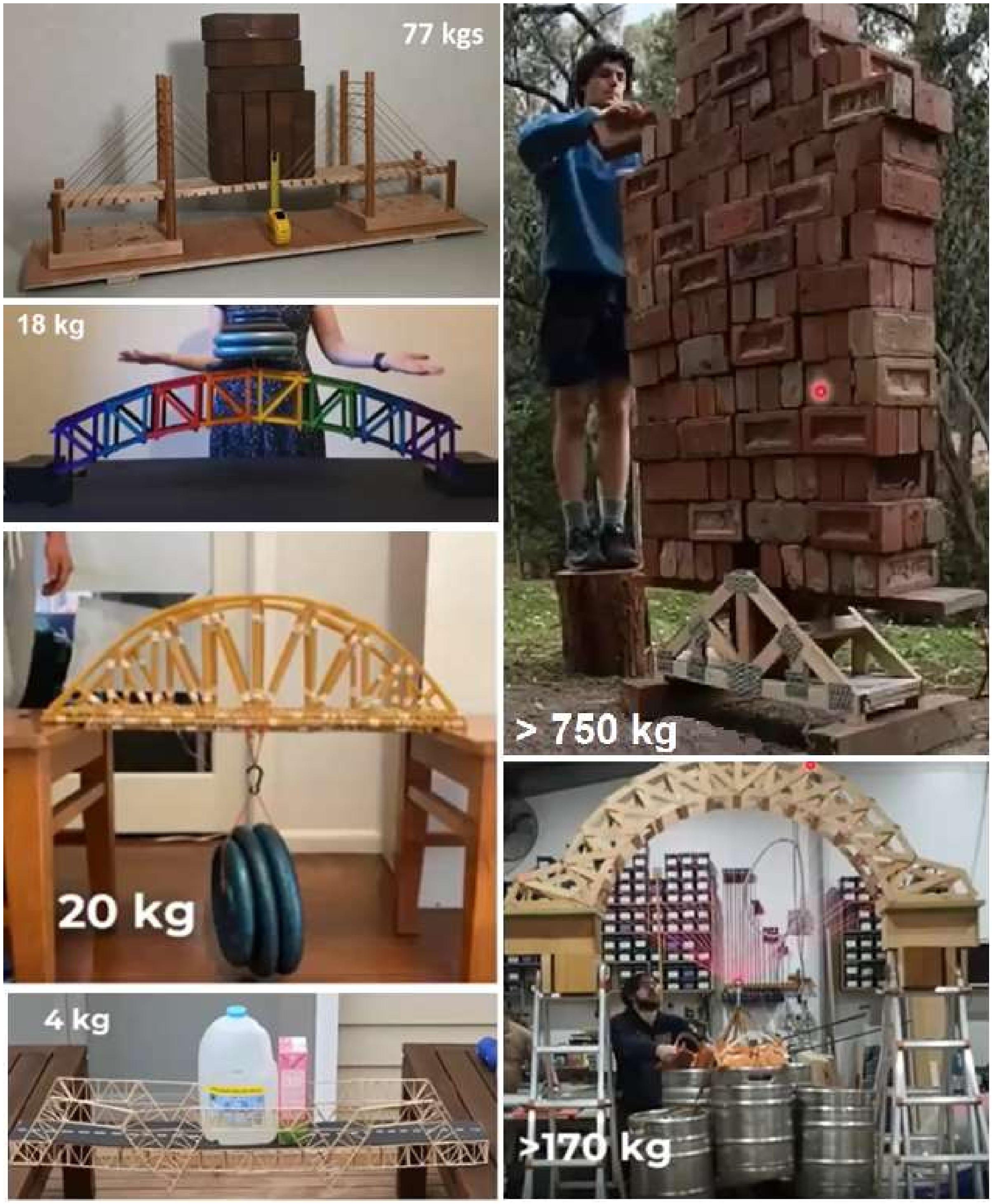


Figure 1: Build-and-test-at-home bridge assignment – some example builds and their load capacities

Despite these differences, the popularity of the build-and-test-at-home bridge assignment, as gauged from the Subject Feedback Surveys (SFS) and CANVAS quizzes for this subject during the 2020-2021 Covid restriction period, was overwhelming. Some student comments:

"I'm stoked about the bridge design replacing the exam, makes the content more engaging and in my opinion helps tie all the content together as its being understood by hands on work." - 2020 S1

"I found it a great opportunity to turn the method I had learnt into real skills, I enjoyed the freedom of the exercise and competing with my friends to see who could hold the most weight." - 2020 S1

“I really loved being able to make something during lockdown”. - CANVAS quiz survey S1 2021

“The bridge project is really interesting and allows us to put what we have learnt into practice.” - CANVAS quiz survey S1 2021

“The bridge project makes the unit really unique” - CANVAS quiz survey S1 2021

“Extremely exciting assignment” - CANVAS quiz survey S1 2021

Authentic learning around real-world problem-based scenarios, (such as the bridge building exercise of ENG10003 run during 2020 and 2021), is one of the most effective ways for enhancing online engagement and learning according to Britt (2015) and Meyer, (2014) and this view has been corroborated by student comments from surveys conducted during this period.

There has been increasing concerns about academic integrity due to *contract cheating* which refers to “outsourcing of student work to third parties” (Lancaster & Clarke, 2016), especially when it comes to assignment work used for student assessment. Bretag et al. (2019) recommended that institutions ensure “*students have understanding of the assignment requirements and receive sufficient feedback*” as a starting point to address contract cheating. The staged interactive sessions for the major bridge building assignment, together with the nature of the presentation of student work for assessment (involving video evidence of the actual construction of their build and its testing) goes a long way towards arresting the potential for contract cheating in ENG10003.

Understanding the first-year students’ experience, (from student surveys) plays a critical role in retaining students, according to Krause (2005). Addressing elements of negative feedback and further enhancing elements of positive feedback, from such surveys in the first-year subject ENG1003, would therefore be quite sensible in reducing drop-out rates in 1st year.

It therefore became “a given” that the bridge-building exercise would be retained by the subject co-ordinator as a major assignment in ENG10003 in the post-Covid delivery of this subject.

Hybrid delivery model for ENG10003 in Semester 1 2022

A hybrid delivery model was adopted in Semester 1 2022 for ENG10003 in which lecture material was presented online and the 2-hour weekly Practice Class/Tutorial sessions run as face-to-face (F2F) on campus in class groups of a maximum number of 24 students in each. The room used for these classes has a complement of 24 computers for conducting online tutorials and tests personally by students, as well as desk space for performing hands-on experiments by students working in pairs using experiment test rigs from the TechnoLab™ EL platform.

The rather small cohort of 106 students in this subject for Semester 1 of 2022, (the cohort in Semester 2 is typically approx. twice that of Semester 1 as this subject is common to all sub-disciplines of Engineering in the first year of their respective courses) resulted in six slightly disparate groups to satisfy student class-time availability and 24-student maximum capacity.

In addition, some special approx. weekly sessions were run online (of particular value to overseas students and those residing far from campus), that allowed for staged assistance and interactive feedback in the subject. These sessions were especially useful to students for performing the throughout-semester major assignment, the EL Bridge-building exercise, now labelled as the “DIY Bridge” assignment for the post-Covid version run in 2022.

Activities in Practice Class/Tutorial sessions

The weekly 2-hour Practice Class/Tutorial sessions provided further options for continuous assessment over the 12-week semesters, in 2022, in the form of regular Pearson Mastery assignments and tests (Pearson, 2022), run online in these sessions.

Most pertinent to this paper is that these sessions also provided an additional opportunity to enhance the EL experience of students in this ENG10003 subject by introducing four separate smaller hands-on experiments with topic-focused learning objectives. These mini experiments supplemented the EL from the two major whole-of-session TechnoLab™ experiments reintroduced as hands-on in 2022, post the two Covid restricted years when these necessarily had to be presented to students online as video-labs. The spread of Practice Class/Tutorial activities is detailed on a week-by-week basis in Table 1. Note that session activities involving hands-on EL opportunities are so designated as this "type" in the table, and also colour highlighted to more clearly stand-out.

The weekly Practice Class/Tutorials commenced in Week1 with a session to introduce students to: the subject and its planned delivery modes; the assessable components and methods of conducting assessment (e.g. some peer review was exercised in the assignment work); the tutors involved in these sessions; general subject resources and the Pearson Mastery online platform.

The percentage scores from the grouped Practice Class/Tutorial activities, together with scoring for the "DIY Bridge" major assignment and the Final Test, as allocated towards overall student assessment for subject ENG10003 are presented in Pie-chart form in Figure 2.

It is clear from this figure that there's a dominance in scoring towards overall subject assessment derived from its EL aspects, namely the "DIY Bridge" major assignment, the two hands-on formal whole-of-session TechnoLab™ experiments and the four TechnoLab™ mini experiments.

It is also clear that SUT has moved its subject assessment strategies more towards continuous forms of assessment for activities that are hands-on experiential in form and involve no more than two members when being run as a group.

Table 1: Activity in weekly Practice Class/Tutorial sessions in ENG10003 (in 2022)

Week	Topic/Activity	Type
1	Introduction to Pearson Mastery	online
2	Topic: Force Actions and Equilibrium	
	Mini-Expt: Equilibrium of Planar Forces acting at a Point	hands-on
	Assignment in Mastery	online
3	Topic: Force Actions and Equilibrium	
	Mini-Expt: 2-D Equilibrium of a Rigid Bar	hands-on
	Assignment in Mastery	online
4	Topic: Force Actions and Equilibrium	
	Test in Mastery	online
5	Topic: Analysis of Pin-jointed Trusses	
	Mini-Expt: Forces in a 2-Bar Truss	hands-on
	Assignment in Mastery	online
6	Topic: Analysis of Pin-jointed Trusses	
	Test in Mastery	online
7	**Expt 1:** Forces in a 7-Bar Warren Truss & Principle of Superposition	hands-on
8	Topic: Flexure - Shear Force & Bending Moment	
	Mini-Expt: Reactions in a non uniform Beam	hands-on
	Assignmentt in Mastery	online
9	Topic: Section Properties of Structural Members	
	Test in Mastery	
10	**Expt 2:** Shear & Bending Moment Diagrams in a Simply-Supported Beam	hands-on
11	Topic: Stresses (Axial, Direct, Shear, Flexural Stresses	
	Test in Mastery	online
12	Revision Session	

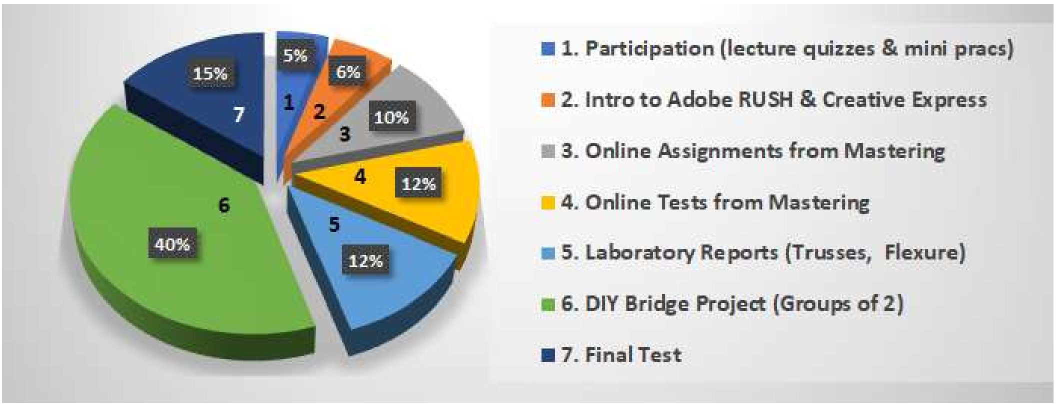


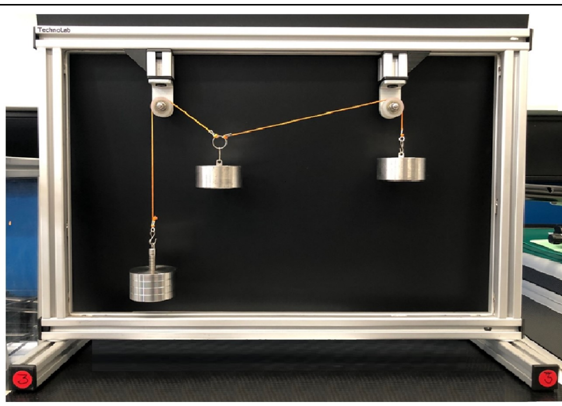
Figure 2: Assessment components for ENG10003 in 2022

Introduction of the four mini experiments in ENG10003

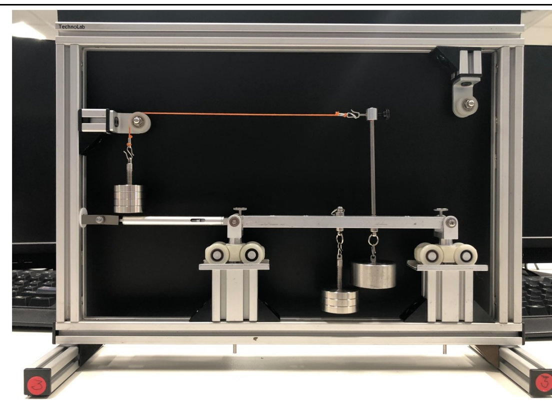
Figure 3 provides photographic images of examples of the initial four TechnoLab™ mini experiments introduced for hands-on performance by ENG10003 students working in pairs.

As this was the first-time introduction of these mini experiments in Practice Class sessions of a maximum of 24 students in ENG10003, four replicates of each configuration were deemed sufficient for each session as their execution was estimated to take less than just a few minutes.

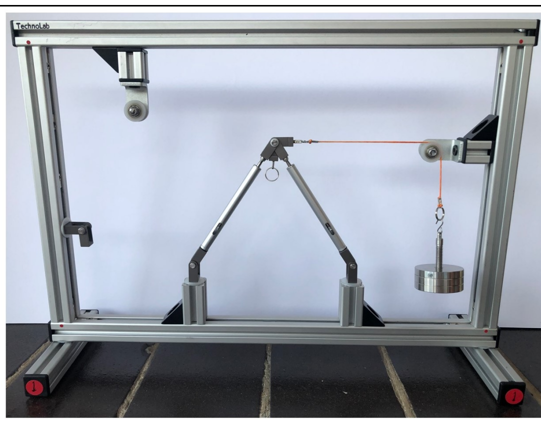
This meant that the class would need be “split” into up into three sub-groups of eight (a student pair for each of the four mini experiment replicates) and the set of four test rig replicates passed



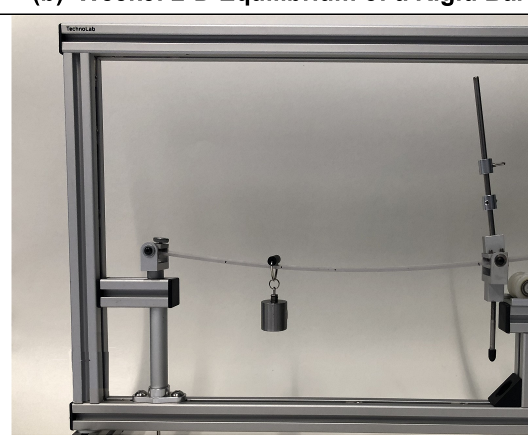
(a) Week2: Equilibrium of forces at a point



(b) Week3: 2-D Equilibrium of a Rigid Bar



(c) Week5: Equilibrium of a 2-bar Truss



(d) Week8: Reactions of a non-uniform beam

Figure 3: The four hands-on TechnoLab™ mini experiments run in ENG10003 in 2022

over to up to two successive sub-groups (only one if that particular class had sixteen or fewer members in attendance) until all class members at the session concerned had experienced performing that experiment with their partner member as a pair.

Experiential learning attributes of the four mini experiments

The four mini experiments share several attributes that are common to the patented TechnoLab™ EL platform that supports experiment test rigs in a wide range of thematic topics in Statics, Mechanics and Dynamics.

These general attributes include: test rigs designed to provide an easy-to-see response to loading ie test specimen “performance”, (e.g. deflected shapes, rotations at pin-supports; movement of roller supports, etc), the use of simple yet highly accurate digital scales for measurement of reactions (via reaction rods); use of non-intrusive 2-D photogrammetry for very accurate mensuration of movement in experiment test specimens (such as deformations/deflections), and an attractive and engaging setup from which it is easy to perform the experiment and obtain specific results of the lesson for which the particular experiment test rig is focused to elucidate.

Specific additional attributes to the general ones listed above, associated with the four mini experiments are listed in Table 2. The flexibility in choice of parameters/test conditions afforded by all four experiments allowed for variations to the actual details of arrangement/setup/loading not only between the four replicates themselves but also between sub-groups, thereby providing a large number of independent test conditions for each mini experiment.

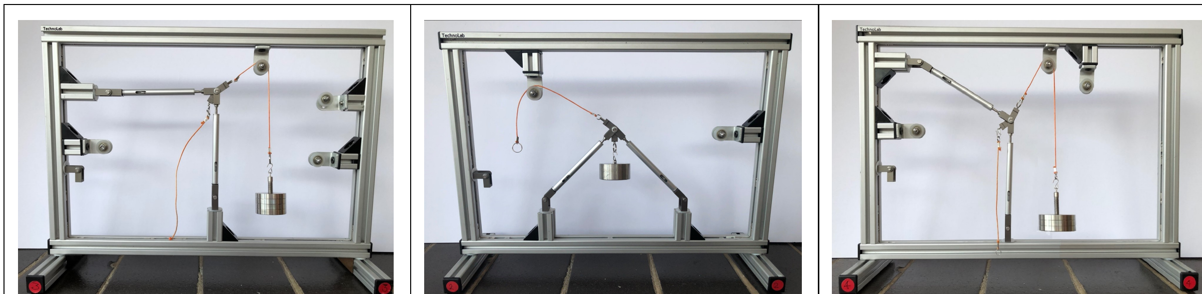
This flexibility is illustrated by way of example for the case of the Week5 mini experiment – Forces in a 2-bar Truss. Figure 4 depicts the additional 3 variants to the initial configuration depicted in Figure 3(c) of this mini-experiment - the 60 degrees member orientation configuration.

The four replicates of the experiment were set up as in Figure 3(c) and Figure 4(a), (b) and (c), to complete the set. Loading that was applied at the intersection node of the two members was of the same intensity and took on one of three orientations: vertically downwards, or via a string passing over one of the pulleys to provide a desired angle of orientation. Examples of these orientations can be inferred from the pulley locations observed in Figure 3(c) and Figure 4(a), (b) and (c).

Student pairs took their own set of close-up digital photographs (using their smart phones) of each member slot before and after application of the point applied loading. They also took photographs

Table 2: Performance attributes of four TechnoLab™ mini experiments

Week	Mini Experiment Title	Attributes of Test Rig/Experiment
2	Equilibrium of Forces at a Point	Highly visual; variable weights (all three)
3	2-D Equilibrium of a Rigid Bar	Reaction rods; truss horizontal support; choice in load types
5	Forces in a 2-Bar Truss	Choice of member orientation; loads at an angle & vertically
8	Reactions of a non-uniform Beam	Multiple loads; loads at an angle & vertically



(a) 90-degree orientation (b) 45-degree orientation (c) 120-degree orientation

Figure 4: Variants to 2-bar Truss configuration of TechnoLab™ mini experiment of Figure 3(c)

of the experiment test rig in the Test Frame to obtain a photographic record of their experiment configuration and raw data of their results. They used digital scales to record the force (in grams) of the weight force applied at the member common connection node. The movement of the end of the pointer located within the slot of each Truss member can be easily ascertained via a simple 1D photogrammetric approach. The position of the end of the pointer (made visible in the close-up digital photographs) relative to the slot length (13mm), before and after application of the loading, can be accurately determined from these photographs so that the amount of extension (or contraction) in each member can then be determined. The force in each member is then evaluated from the known internal member stiffness times the associated member extension or contraction.

Students were requested to obtain the two member forces via the "Method of Joints" for this test configuration (known load applied at common node joining two Truss members with known angle of orientation) and to compare their analytical results to the experimentally obtained values (sprung stiffness of members their respective elongation/contraction from simplified photogrammetry). Agreement to better than 5% was typically reported.

A brief record of their work – a Word file with pasted photographs of the raw data capture and a photo of their hand calculations - was required of each pair to be uploaded to a repository on CANVAS. This allowed the possibility of future access to these by students in other groups to act as worked examples or for access to the raw photographic data only, in order to evaluate and compare experimental results against values from the "Method of Joints" analysis for themselves.

A similar approach was used to produce repositories in the other three mini experiments, thereby increasing the potential value to students in the subject of recording the raw data together with the follow-up analysis. A rich set of raw and analysed data for a range of test configuration conditions would thus be amassed. The uploads also served as record of students having attended and performed the mini experiments, complementing their online tests/assignments at these sessions.

Student feedback on ENG10003 - EL components

Student Feedback Surveys (SFS) and Canvas quiz surveys were conducted in ENG10003 in semester 1, 2022 for the two formal TechnoLab™ experiments and the newly introduced mini experiments. Feedback on the DIY bridge building major assignment was only specifically requested in the SFS for the subject. The "general comments" section of the SFS allowed additional opportunity for student feedback on any aspects of the delivery of ENG10003.

Some highly complementary comments were received for delivery of the subject as-a-whole e.g.

"i really appreciate how the unit was structured. overall the lectures/assignments/weekly-tests and Lab sessions combined together made it a very fun unit."

"Found it a great introduction to mechanics, although this is not what I will be majoring in and what I hope to be doing in the future, it's essential in being an engineer."

"The weekly practical sessions are the best part of the unit as it helps to learn the principals of mechanics more efficiently."

"good to see real life modelling of theory"

However, there was also some conflicting feedback received concerning mini experiments, e.g.:

"The mini pracs were nice to include but I feel they could be better structured because we did not know what we were doing until the experiment was over and the calculations were done. It would be nice if those can have a brief in the beginning just like the main labs do."

"I love the prac sessions and it would be nice to have more of this"

Feedback on DIY bridge building assignment

Student feedback on the DIY bridge building major assignment remained as highly complimentary as for during the two Covid lockdown years. This single student comment is considered typical:

"*Actually building the bridge is the best part of it (the subject) according to me. It allows us to put all the things we learned to use and is a nice experience overall.*"

Feedback from CANVAS quiz survey on TechnoLab™ formal and mini experiments

Details of student feedback scores on a short (6 item) CANVAS quiz are presented in Table 3. It is clear that students who responded (24% of cohort) rated the experiments as "Good" to "Excellent".

Table 3: Student feedback on TechnoLab™ formal and mini experiments

Question/Item for Rating	Excellent	Good	Fair	Poor/NA
Relevance of mini experiments in tutorial to theory	43%	39%	17%	0%
Helpfulness of mini experiments to supplement lecture & tutorial materials	39%	39%	17%	4%
Relevance to theory of Week 7 truss lab	57%	22%	17%	4%-NA
Helpfulness of Week 7 lab experiment in understanding how a truss behaves when loaded	65%	17%	9%	4%; 4%-NA
Relevance to theory of Week 10 lab on bending moment and shear force diagrams	30%	61%	9%	0%
Helpfulness of Week 10 lab in understanding how beams behave under bending	43%	43%	13%	0%

Concluding Remarks

The return in 2022 to a hybrid delivery of subject ENG10003, Mechanics of Structures, at SUT featured significant hands-on Experiential Learning opportunities to students that included a DIY whole-of-semester bridge building major assignment, two formal reports on performance of TechnoLab™ experiments and the first-time introduction of four TechnoLab™ mini experiments.

Student responses to Subject Feedback Surveys and CANVAS online questionnaires, relevant to these EL components, provided overwhelming evidence of the popularity and learning experience gained from the bridge building assignment and a high appreciation of the value of hands-on experimentation towards the understanding and learning of the focused topics these treated.

Teething issues reported on the first-time introduction of the mini experiments to this subject, as reported from these surveys are being addressed for improving upon their treatment in semester 2.

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