INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
8–9 SEPTEMBER 2022, LONDON SOUTH BANK UNIVERSITY, LONDON, UK

ARTICULATING MODERN ENGINEERING CHALLENGES USING AN ARTEFACT STUDY THROUGH TIME

Jeff BARRIE
School of Civil, Aerospace and Mechanical Engineering, University of Bristol, United Kingdom

ABSTRACT
Typically, an artefact study allows engineering students to dissect a product or device to understand its inner mechanical workings, manufacturing and materials. This paper discusses a broader artefact study which asks students to choose a man-made artefact from the 20th century or earlier and discuss the implications of designing or constructing such an artefact in the 21st century. Students were asked to consider contemporary design processes, changes in market needs as well as a deeper appreciation of the environment, socio-cultural issues, sustainability, ethics and climate change. For example, what if the Great Pyramid of Giza was constructed today? What if the Sinclair C5 was a new sleek, contemporary, and modern form of transport for 21st century commuters? First year engineering students were asked to choose an artefact that was interesting or meaningful to them-and encouraged to consider design changes, new technology and new needs and challenges associated with the 21st century. The work produced from the students was fascinating and insightful; showing that modern engineers can learn from the past.

Keywords: Artefact study, reflection, sustainability, Engineers Without Borders, curriculum design

1 INTRODUCTION
As part of a new introductory design unit, 700 first year engineering students from a broad range of disciplines were given key knowledge, skills and competencies essential for 21st century engineers. This entailed hands-on workshop and practical skills, Health and Safety inductions and electronics, an ice-breaking group design project supported by Engineers Without Borders, as well as developing skills in technical drawing and Computer Aided Design (CAD). The unit was also supported with asynchronous design content using online video-based lectures and activities, supported with weekly online drop-in sessions. The content covered key unit learning outcomes which were difficult to achieve through practical, studio-based work alone. This included an introduction to design processes, how to define and bound an engineering problem and seek new opportunities, as well as appreciating 21st century challenges engineers face, such as sustainability, ethics, socio-cultural factors, design for the environment and the climate emergency. The unit (part of a new curriculum) was designed to act as a foundation for all engineering students in the school, to give them key professional engineering and design skills as well as basic knowledge that will support them in discipline specific project and design units they will undertake the following term. As such the unit had to be sufficiently broad and relevant to a range of engineering disciplines, from Civil Engineering to Electrical Engineering.
Students were introduced to the design process, teamwork and global responsibility by undertaking the Engineering for People Design Challenge with Engineers Without Borders in the first week of university, with randomly selected 4-person teams from their larger teaching groups. For some students, their first day as an engineering student was to be inducted in Health and Safety practice and the University workshop and lab spaces (much like workplace training). These activities set a precedent to what the expectations and responsibilities are for a 21st century global engineer.
The studio-based activities focused on basic technical drawing and CAD exercises (part of what was called a skills certification) which formed part of their portfolio of work. Throughout the unit the students were introduced to weekly topics on design via online lectures, and to complement the new direction of teaching, the final piece of coursework students were expected to deliver was an essay based

artefact study and individual reflection (reflecting on teamwork, skills and competencies learned in the unit). An overview of the unit schedule and parallel activities can be found in Figure 1.

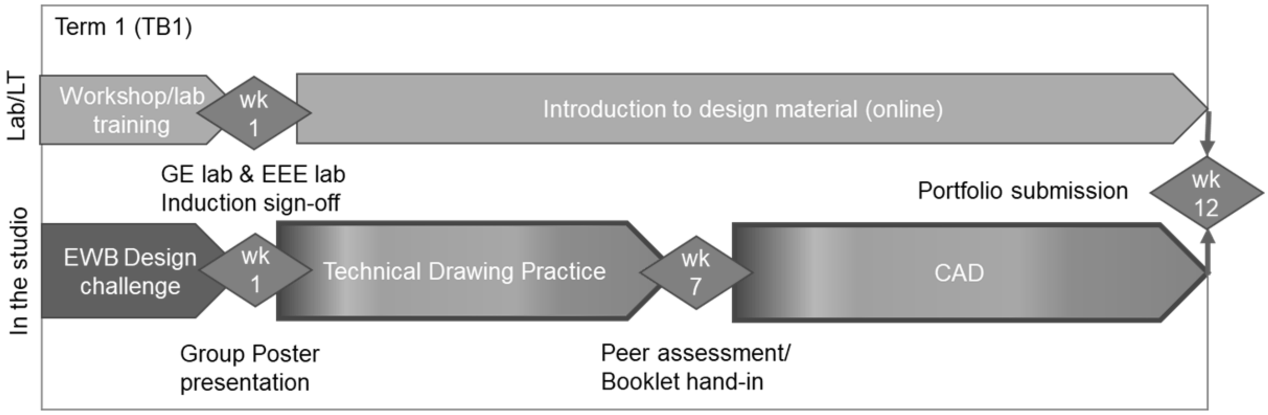

Figure 1. Unit content over the term

2 A DIFFERENT TAKE ON A TYPICAL ENGINEERING ARTEFACT STUDY/MECHANICAL DISSECTION

The original idea of the artefact assessment was to allow individual students to design and make their own artefact using their newfound CAD and technical skills. Unfortunately, this was not feasible due to the scale of the unit, the burden on the workshops and labs at a busy period during term as well as the timing of CAD sessions which would leave little time for students to develop their own designs. There was also the issue of mapping the assessment to some of the trickier design-focused Intended Learning Outcomes (ILO's) of the unit (as the group design activity was formatively assessed). Instead of creating their own artefact, students were instead asked to undertake a study of an existing engineering artefact.

A study of an engineering artefact (or mechanical dissection) is an approach identified in the teaching of engineering design, in particular Stanford University's ME99 Mechanical Dissection course where students learn the *"vocabulary of mechanical systems"* to Strathclyde University's vehicle dissection, introducing first year Mechanical Engineering students to component functions, materials, manufacturing and analysis [1].

Stanford took a broad approach to mechanical dissection (as it's not *just* about taking things apart and finding out how they work) by building students awareness of the design process and improving their communication skills. When the ME99 course launched in 1999, it was offered to students who did not fit the target criteria of an engineering major-but were curious about the world around them. In general, the course provided an opportunity to be more inquisitive and take a problem-solving approach to their learning [2].

Strathclyde's approach also allows students to build an awareness of the design process and develop communication skills but is more group-based (most likely to cope with the cohort size) and took a more analytical approach. [3].

Whilst it is acknowledged that a hands-on mechanical dissection is a useful activity in satisfying an engineering students curiosity of how things work and how they are made, the constraints and challenges of offering a such activity to a large cohort of students is also highlighted in a study by Armstrong Atlantic State University (AASU) which used multi-media technology to provide students with a virtual strip-down of the components of an electric toothbrush-which generally yielded positive results and comments-and provided an alternative method to the traditional lab or workshop-based approach [4].

The dissection activities described at AASU, and Strathclyde dealt with cohort sizes of 190-200 students. Given the constraints on the lab and workshop spaces, a typical mechanical dissection-based approach would not be suitable for a broad engineering course with 700 students, given that the cohort was mixed discipline and the first year Mechanical Engineering students within the cohort had yet to undertake any units on machine components, mechanisms, material or manufacturing.

Another observation from the mechanical dissection activities described in Stanford, Strathclyde and AASU is that there is little or no consideration of sustainability or environmental impact. Given the findings are from 2010 or earlier indicates that such considerations were not as critical at the time and may have subsequently been included in the curriculum.

With such focus on materials, function and analysis, the engineering approach to studying an artefact is somewhat different to that in Archelogy, which help archaeologists not only understand the technical aspects of material and construction, but wider societal aspects. For example, an archaeological approach to understanding artefacts may entail how an object builds into a picture of the society that made and used it, how cultural and economic factors as well as the material properties influenced how an object is made as well as a deeper understanding of the object's biography [5].

Whilst mechanical dissection is still a relevant and useful activity for Mechanical Engineering and Product Design students. An archaeological approach, in a way, would allow a Civil Engineering student to 'take apart' a bridge or building, or an Aerospace Engineering student to understand cultural, economic and societal aspects of a particular aircraft. It is also acknowledged that students do not necessarily need to take a product physically apart to understand materials and function, bearing in mind that AASU developed a virtual approach-and from what is assessed in the activities at Stanford and Strathclyde-students can gain an understanding of the design process and develop their communication skills from the activity.

This approach also maps better to the intended learning outcomes of the unit, which not only asks students to explain the common stages, processes and methods of engineering design but to articulate the wider context of modern engineering challenges, such as sustainability, ethics, socio-cultural issues and climate change. These challenges have been recently highlighted as critical considerations in professional engineering, such that they form a key area of learning for all engineers and their role in society [6].

3 LEARNING FROM THE PAST; AN ARCHAEOLOGICAL APPROACH

By taking an archaeological approach to understanding an engineering artefact or product, students can delve into history, and reflect on the societal and environmental impact of man-made artefacts. There are many interesting engineering artefacts students across time can choose from, such as architectural wonders such as the Great Pyramids of Giza, to the industrial revolution with James Watt's steam engine, not to mention Isambard Kingdom Brunel's iconic Clifton suspension bridge or SS Great Britain, to 20th century innovation in aviation with the Boeing 747 and Concorde.

Such artefacts are discussed as case studies in engineering lectures, and many can be found on posters adorning hallways of most engineering schools. But to engineering students who will eventually be senior professional engineers in the mid-21st century they represent a bygone age-at a time when the world and society was very different-where design for environment and sustainability were alien concepts. Even engineering in the late 20th century now seems outdated, for example the Boeing 777 was the first aircraft to be fully designed using computer-aided design (CAD) software, to reflect a cultural change in design and manufacturing practice. It's a recognizable, modern aircraft still in service today-but in design and development terms it's nearly 30 years old (for anyone under 30-year-old that's 5 generations of the Sony PlayStation).

However, there is a lot that 21st century students can learn from products and engineering artefacts of the past. This concept was recently explored in a paper by engineering academics at the University of Derby, who asked what students can learn about 'ancient' methods that will assist them in computer led design today, and what can be learned from the past that will help them in the future. The paper concludes that students appreciate the use of calculations and appropriate analysis to understand failures of the past [7].

By understanding an engineering artefact from history, students have access to a wealth of information about its conception, development, manufacture or construction and whether the artefact was a success or not. Students can also access decades of information on the societal and cultural impact of engineering innovations, not to mention their impact on the environment and climate change. Such is the gift of hindsight that students now have almost unlimited access to-but one has to bear in mind that the call to action for sustainable development and formation of guiding principles has been around since the 1980s [8].

An important factor to consider was bridging a link with the practices and challenges that 21st century students face now as well as the future-and that of engineering artefacts of the past. Inspiration on how to approach this came in the form of news article from New Civil Engineer, which hypothesized that *"if you were to get a time machine and bring Isambard Kingdom Brunel to your project site, his mind would* *be blown"*[9]. The article comments on the advancements of civil engineering practice, but also remarks on some useful learning of the past.

This led to the idea of a 21st century Brunel, and the changes to technology and professional approaches that one must adapt to. What if the Great Pyramids of Giza were constructed today? What would be the considerations of designing a Boeing 747 or Concorde using modern aerospace practice and materials? These questions formed the basis to how students were to be individually assessed on their understanding of 21st century engineering challenges and design processes.

4 THE DESIGN PORTFOLIO

The artefact study formed part of a portfolio of coursework that assessed students on their understanding of the unit outcomes, which included a personal reflection on the skills and knowledge each student has learned on the unit, as well as the challenges of teamwork within the Engineering for People Design Challenge. Students also submitted technical drawing exercise and CAD work. Overall, the portfolio of coursework was assessed under Pass/Fail criteria due to the skills and competency-based approach to the unit assessment. Where students could express individual creativity, and allow some differentiation between student coursework, was the artefact study.

Students were encouraged to choose an engineering artefact, from the 20th century or earlier, that they were interested in or had some sort of meaning to them-preferably affiliated with their programme of study.

Some examples were given to the students, to help them understand the context of the exercise, and dialogue with students helped develop some interesting ideas. For example, some approaches on a modern Pyramid of Giza included not only using modern building materials but appreciating the current socio-cultural situation of modern day Egypt. Ideas included a multi-purpose building that could be used more by the community (rather than a tourist site)-other ideas included a centre for displaced Syrian refugees, or a venue for underground Egyptian street music (a modern day Pyramid does exist, in Memphis as a Bass Pro shopping centre, which includes an alligator habitat). See Figure 2.

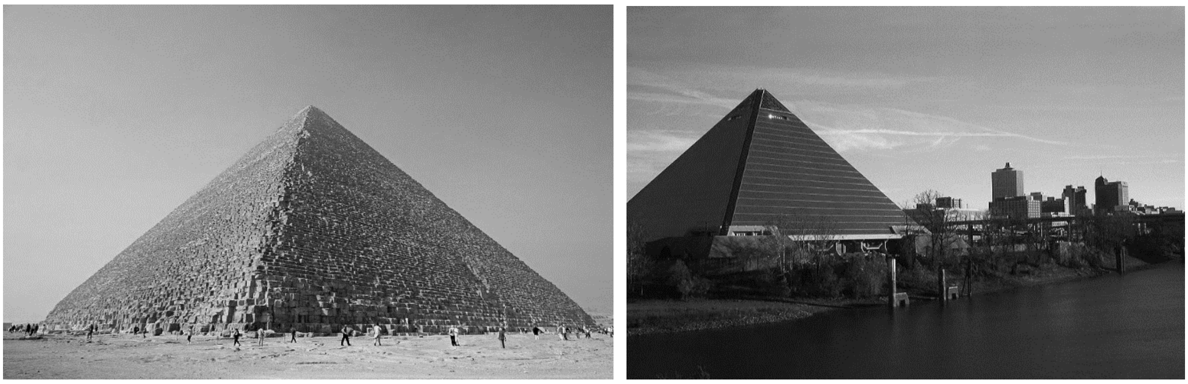

Figure 2. Right: The Great Pyramid of Giza and Left: The Memphis Pyramid (Wikipedia)

The Boeing 747 was also used as a case study example, where its iconic fuselage design is in part influenced by its end-of-service life as a cargo aircraft (the fuselage is big enough to fit a container into it) which students were quick to point out it's re-use cycle in a Life Cycle Assessment. Students were also able to appreciate the environmental impact of carbon fibre usage balanced with weight reduction and subsequent reduction of fuel. Students were also able to appreciate the design process using this example, as early concepts of the 747 included ideas not too dissimilar to (the now withdrawn) Airbus A380, and a daring concept that had the cockpit positioned at the bottom.

Another case study example was the Sinclair C5, a 1980's invention and transport revolution that did not meet commercial success. By investigating the Sinclair C5 in a modern context, students were able to appreciate the changes in society and explore new needs and opportunities in sustainable transportation in cities, such as taking advantage of lightweight material and improved battery technologies. See Figure 3.

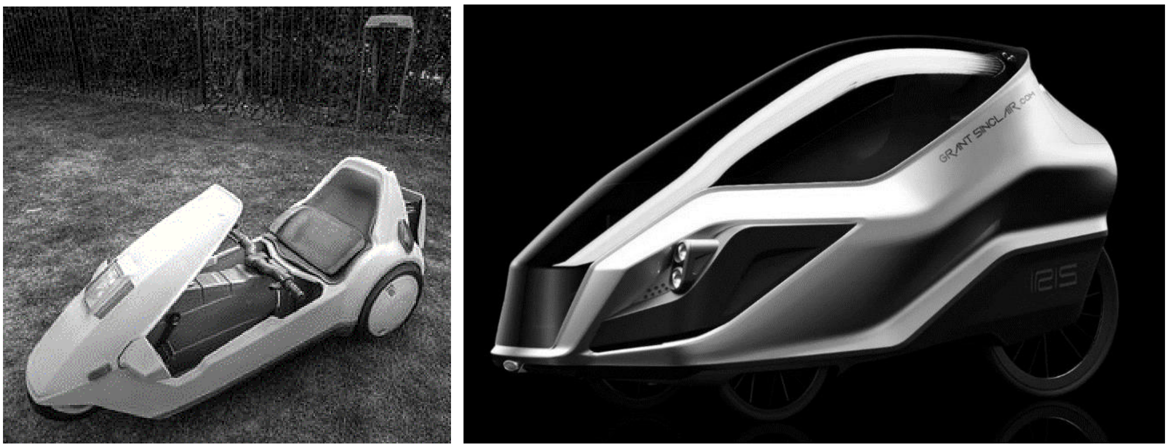

Figure 3. Right-Original Sinclair C5 (Wikipedia) Left-Sinclair C5 update (Telegraph)

5 DISCUSSIONS AND CONCLUSION

Students feedback on the exercise was mixed, for some they did not understand the context well, and preferred to work within the safe confines of the case study examples used (rather than choose their own artefact), others misunderstood the exercise and provided a history of the artefact, as opposed to a reflective study of how it fits into the 21st century and associated challenges. Another consideration was the online delivery of lectures, and expectation for students to work on the artefact study as out-of-class coursework. Much of the unit delivery was studio-based and thus focused on the more practical sides of the coursework which could be facilitated in such an environment. Some students struggled with the format, given they had little experience of essay-based or reflective writing. Nonetheless, many of the artefact studies submitted were thought provoking, insightful, varied and sometimes deeply personal.

For a first-year student, the artefact study provides a broad introduction to design processes and 21st century challenges facing engineers today-and provides a deeper insight into the socio-cultural, environmental, and ethical impacts of engineering artefacts. However, the artefact may be more appropriate as a consolidation tool rather than a summative form of assessment, and possibly more useful in latter stages of study after first year students gain the essential knowledge and skills they need as a foundation. The artefact study seems more suited to an activity where students can deepen their research skills and develop and integrate their engineering knowledge.

Nonetheless, the archaeological approach to an artefact study does have enormous potential to help engineering students to understand the context of 21st century engineering as well as their place and responsibility in the world, beyond just taking things apart and seeing how they work.

REFERENCES

[1] McLaren A. Approaches to the Teaching of Design. *The Higher Education Academy Engineering Subject Centre*, 2008.

[2] Sheppard S. D. Mechanical dissection: An experience in how things work. *Proceedings of the Engineering Education: Curriculum Innovation & Integration* (1992): 6-10.

[3] McLaren A. J. and Jenkins P. Mechanical dissection in an introductory engineering design module. *6th International CDIO Conference*. 2010.

[4] Goeser P. T., et al. A VIEW on Mechanical Dissection for Freshmen Engineering. *Proceedings of the American Society for Engineering Education South East Section Annual Conference*. 2010.

[5] Caple C. Objects: Reluctant Witnesses to the Past. *Routledge* 2006.

[6] The Accreditation of Higher Education Programmes (AHEP) 4th Edition. *Engineering Council*, 2020 p35.

[7] Sole M., Barner P. and Turner I. Mechanical Engineering Design, Does the Past Hold The Key To The Future? *International Conference On Engineering & Product Design Education 9-10 September, VIA Design, VIA University College, Herning, Denmark* 2021.

[8] Brundtland G. H. Report of the World Commission on Environment and Development: Our Common Future *World Commission on Environment and Development (WCID)* 1987.

[9] Bajrakurtaj E. The Future of Engineering Means Bringing Back The Construction Of Brunel 2021 [Last accessed from *https://www.newcivilengineer.com/latest/the-future-of-engineering-means-bringing-back-the-construction-of-brunel-07-03-2021/* on 10/03/22].