

CAD BASH: ACCELERATING 2D/3D COMPUTER AIDED DESIGN COMPETENCIES FOR FIRST YEAR PRODUCT DESIGN STUDENTS

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ABSTRACT

The everchanging technological/digital landscape of the Product Design (PD) and Product Design Engineering (PDE) industry now requires graduates to have a wider range of software skills/knowledge. In particular, there is a need for enhanced skills focused on engineering computer aided design (CAD), virtual reality, 3D visualisation and rendering/animation. This has resulted in graduates requiring a more detailed/rigorous CAD/3D visualisation syllabus to prepare them for industry. With the increased pressures on delivering a wider range of software teaching alongside a greater range of hardware, the need for a good grounding/understanding of 2D/3D engineering CAD competencies is essential. The PD Department at Nottingham Trent University (NTU) identified the need for enhanced engineering CAD teaching/learning within the higher education setting, especially within the first-year PD curriculum. There is the need to challenge established pedagogy and delivery methods with regards to CAD tuition and explore new delivery methods and alternative educational paradigms to allow educators to equip engineers/designers for future industry requirements. This paper explores the development of 'CAD Bash', an accelerated taught SolidWorks 3D CAD syllabus delivered to students in a five-day synchronous format and supported by asynchronous content. CAD Bash was delivered in week two of the first-year BSc Product Design curriculum to sixty-two students. Students perceived skill set was assessed through a skills audit pre and post CAD Bash. This paper presents the findings from CAD Bash and the learner and academic insights with recommendations made regarding its future delivery.

Keywords: 2D/3D visualisation & communication, Computer Aided Design (CAD), CAD training & competencies, product design education, skills audit

1 INTRODUCTION

Computer Aided Design (CAD) has become one of the essential parts of design education in higher education (HE) [1], especially within UK PD courses [2]. However, in recent years scholars have been exploring alternative ways to deliver CAD sessions, whether this be through project-based learning due to the impact of COVID-19 [3] or by exploring approaches to allow students to be more successful attaining professional accreditations i.e., Certified SolidWorks Associate/Professional (CSWA/CSWP) [4]. It can also be argued that learning more than one 3D CAD software package is essential [5] within design/engineering education considering the demands of modern-day manufacturing and the blend of disciplines many industry roles now require. Furthermore, the demand from industry also requires graduates to have a greater understanding of the wider industry needs/requirements especially in relation to sustainability implications [6], the circular economy, digital manufacturing etc. As such, PD education needs to adapt to ensure students understand how to use complex features within software packages such as life cycle assessments, but first students must fully understand the fundamentals. At NTU, weekly engineering 'CAD Lab' tuition has been adopted for undergraduate instruction and progression for many years. Sessions typically last for 90 minutes across all undergraduate PD courses with varying 26-week syllabi across year groups. In recent years it has been discovered that student attainment, and engagement has been wavering, in some instances leading to absenteeism, and deficits in proficiencies. Whether this was due to changing student profiles, and the way in which they learn, or

assumptions by tutors that they would practice outside of the classroom to catch up on anything that had troubled them, it was necessary to discover a way to inject both a level of competency and engender methodologies of approach that could lead to increased engagement, which in turn, allow the students to 'hit the deck running'. At NTU, we deliver teaching across a suite of software programs that aligns to industry partners and design practices with CAD tuition running concurrently with design studio projects. Delivered content allows students to prepare/achieve CSWA/CSWP within the curriculum; it is widely accepted that this benefits and adds value to a student's CV and subsequent graduate employment [7]. Historically, the expected outputs from projects had to be tempered to match the levels of vocational and technical knowledge. Typically, this meant that CAD modelling and visualization within the first year was modest as students went through increasing levels of proficiency. To counter any ennui as the result of the slow climb to competency, it was hypothesized that a 'kick start' from the outset was necessary to allow new first year students to see the potential of industrial practices early on, whilst 'upskilling' them quickly. As such, 'CAD Bash' was developed.

2 CAD BASH & LOGISTICS

The premise of CAD Bash was to employ a new strategy for up skilling first year PD students, to enable rapid progression and positive association within engineering CAD. CAD Bash was designed to complement a weekly design sketching syllabus that introduces engineering drawing principals and supporting studio sessions where engineering drawing interpretation is taught. This pilot program was run with BSc PD students in the second week of the first academic semester. CAD Bash is an accelerated program of eight 1.5/2-hour engineering CAD sessions, held over a five-day period that seeks to give a broad overview of essential approaches/practices. This raised several logistical planning challenges for a cohort size of sixty-two students. At NTU our pedagogic approach suggests that student group sizes in taught CAD sessions should not exceed a maximum of 25 students with one lead academic and a supporting colleague. Increasing CAD class sizes beyond this often resulted in retention and attainment issues. With only five CAD facilities available with the required software, each of which varies in size, this posed a logistical challenge regarding group sizes. As such three groups of 20-21 students were setup with two academic colleagues always present. Often due to timetabling restrictions CAD Bash sessions would run concurrently and as such up to six academic colleagues were required to run the concurrent sessions. The student profile also highlighted students with various learning access statements and physical and digital accessibility requirements. These factors needed to be considered within room allocation and tutor allocation. A critical aspect of the curriculum was ensuring all academic staff were well versed in the syllabus, ensuring consistency in delivery, across the resources.

2.1 Logistics & Content Creation

Vocational lead (Paul Kennea), an academic with over two decades of experience teaching and devising CAD syllabi, developed the CAD Bash approach. The CAD Bash format of delivery was a five-day synchronous course supported by asynchronous content. This asynchronous content was recorded educational videos of the sessions supported by eight PDF instructional documents. Video content produced was a means of backing up the in class taught content; this provided the students with a resource to refer to during or post sessions. These videos allowed academic colleagues to review/deliver the same approach, to ensure consistency and alignment. The content focused on developing 'best practice' providing a solid foundation to build upon. It was key that students understood the parametric hierarchies of SolidWorks, to establish and drive good practice. Content needed to be NQF Level 4 relevant, and as such technical tuition was delivered in a manner that was clear to students, adopting an iterative approach, starting simple, and slowly building in complexity, through simple tools. The purpose of the syllabus was to provide students with the skills to build accurate 3D models, singular or multipart assemblies, and then produce elevational technical drawings. At every stage it was key to maintain an industrial bias, whilst at the same time not unnecessarily overwhelming students who are often naïve to the process. Critical to all the activities was to develop independent thinking and embed an approach akin to that used within industry. Activities started with fairly simple extruded and revolved forms, increasing complexity through sketch work (driving extrusions and revolves), and technical sheet layout.

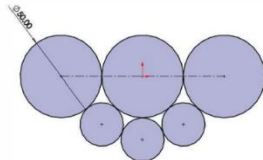
2.2 CAD Bash Sessions & Structure

CAD Bash was structured into eight separate sessions with distinctive learning outcomes and topics assigned. Session 1 focused on introducing SolidWorks, the software interface, the production of basic

sketches/elevations and sketch relationships/parameters. Session 2 focused on rotational and revolving entities within 2D & 3D sketches alongside dimensioning. Session 3 explored sketches with extruded boss/bases and creating a 3D part from a 'nested' sketch using selected contours. Session 4 explored more complex sketches and sketch relationships, alongside 3D feature commands such as boss/base extrude, shell and hole wizard. Session 5 explored revolve boss/base features and understanding drawing conventions. Session 6 focused on drawing tools by creating technical drawings which clearly define and convey all the necessary technical information derived from SolidWorks modelling. Session 7 explored the creation of 3D components with the restriction of specific 3D features/tools such as revolve and revolved cut boss/base. This session also introduced basic assemblies and the production of general assembly (GA) drawings with content derived from modelling parameters and properties. Finally, Session 8 explored assemblies/sub-assemblies by assembling a Lego Figure and Lego Fire Boat. During the first few sessions, students were introduced to the SolidWorks interface, and the first stage of CAD development i.e., sketch/2D Drawing. Tuition on how 'sketch tools' worked, allowed the teaching of defining sketches through a fixed datum. After experimenting with sketching, students undertook a quiz with six key questions challenging them to draw and full define sketches (Figure 1).

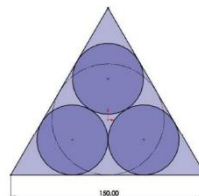
Sketch Relations Test.

Q1. Sketch the following. All Circles in contact are tangent. Larger circles are equal and align horizontally. Small circles are equal. Sketch must be defined. Only Circles are required to be drawn.



Q. What is the diameter of the smaller circles?

Q2. Create the following equilateral Triangle (Tip polygon sketch tool). Create three circles tangent to all touching circles and lines. Sketch must be defined.



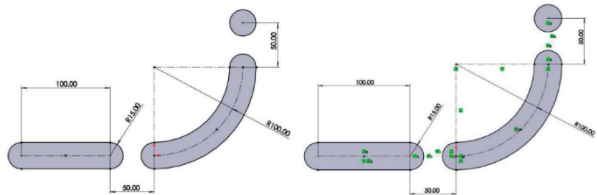
Q. What is the diameter of the circles?

Figure 1. Examples of Sketch Relations Questions

This quiz was designed to check the students learning in relation to their familiarity with sketch tools, their understanding of construction approaches and defining through 'relations', dimensions, and datum. This helped to establish the 'rules of engagement' at an early stage when using sketch tools i.e., sketch then define (both sketch relationships and dimensions), and anchor to a datum. Later tasks (Figure 2) reinforced approaches to define sketched forms before exploring 3D forms.

Sketch on the 'Top' plane.

Create the following. Fix the '3 point slot' onto the UCS (Origin). Right view (Showing Relations).



Let's make it 3D.

Features:

Extruded Boss/Base: Mid Plane Extrusion 30 mm

Fillet: 15 mm

NB: You'll need to use 3 fillet commands on this 'Multibody' result.

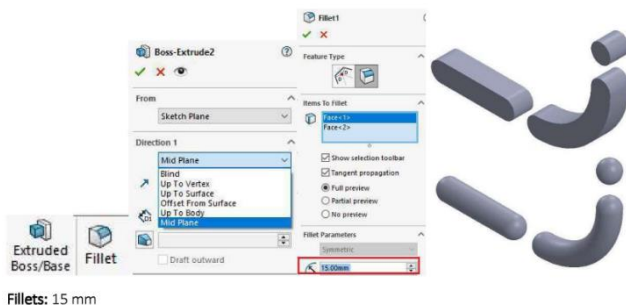


Figure 2. Examples of Sketch Relations Questions

Later sessions challenged students to understand the logical ordering of steps to accomplish a given task (Figure 3). Typically, the examples presented in the sessions fully explained the modelling methodologies by breaking it down step by step. This was supported by handouts with text explanation and screen shots and further enhanced by the accessible in session videos. Subsequent questions/activities followed a similar process; however, students were then supplied with only technical elevations of a form/product, with the expectation that they use the learnt methodologies to produce the correct CAD output. Again, if a student struggled, tutors and videos would help them resolve any issues. It was found that in most cases, students enjoyed the challenge; several students didn't require video support (22%), though at times still sought guidance from the teaching staff. By the start of Session 4 the students had completed 4.5 hours of SolidWorks tuition. Prior to the start of CAD Bash, typically 80-90% of students were previously unfamiliar with the application; within this cohort 83% of students had never used SolidWorks before. Session four whilst using simple tools, starts to challenge the

students by bringing complexity through technical annotation, and designed features. Again, whilst this was fully broken down by a step-by-step approach, additional/new approaches and tools were introduced, including the use of feature wizards (Figure 4).

In today's session, we'll look more closely at technical drawings, and how we may be able to both read them and implement a strategy towards creating the 3D model from them.

Tools: Sketching, relations, Boss/Base Extrude, Hole Wizard.

We'll create the following, but with a 'guided' hand. I'll show you my approach and why.

So, the product 'spearhead' below, looks complex, but is made up of only a few simple features. However, this can be misleading, and in this case, we'll need to be clever, in the use of these tools, and look much more into how they operate. First however we need to determine what sketch plane to use, and the approach thereafter. For me it's to sketch the 'spearhead' profile in the TOP view.

Exercise 1. 'spearhead'.

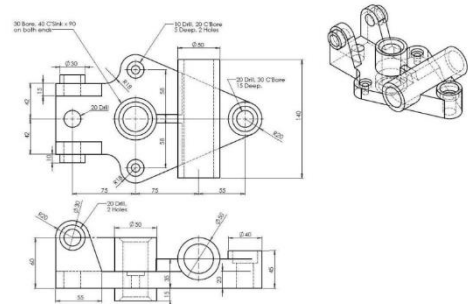


Figure 3. Wedge Lift Activity Step By Step (Left); Wedge Lift Activity Reference Drawing (Right)

Select bottom Face, then new sketch: Create a 'Straight Slot' iso, and plan view.

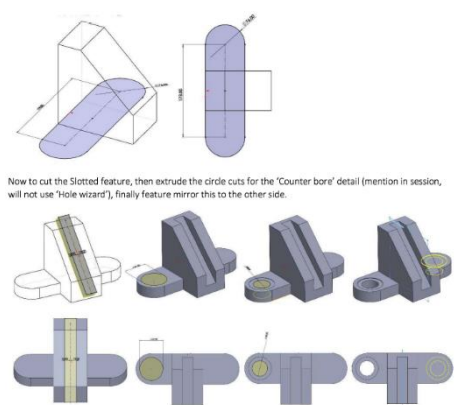
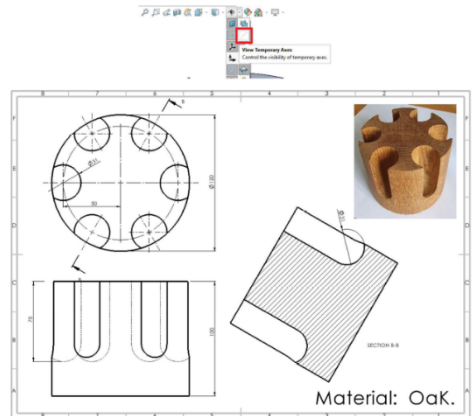


Figure 4. Technical Elevation Worksheet (Left); Hole Wizard Feature Using Derived Values (Right)

Often the biggest challenge when modelling in CAD is the route to take. Tools to use, approaches etc. In this instance you are tasked with creating this part with **ONLY** the Features: **Revolved & Revolved Cut Boss/Base**, no extrusions, maybe used. You will need to use the Feature tool: **Circular Pattern** and switch on 'Temporary Axes', for the revolution Axis.



Let's now create an exploded view technical Sheet. First, we'll need to explode the assembly.

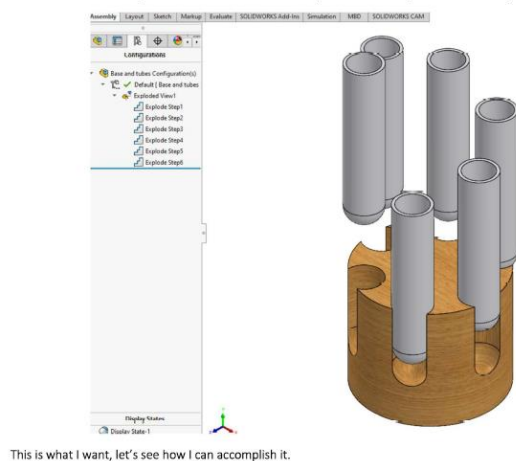


Figure 5. Technical Elevation Worksheet Featuring Revolved Features & Assemblies

By Session 7, students were now showing a very good level of independence, using critical approaches to interrogate technical elevation drawings and produce varying 2D/3D forms in SolidWorks. As such Session 7 now 'throws a spanner in the works' by challenging the students to model using restricted features. Students are faced with questions such as "What if you are unable to use an approach that seemed the simplest?" Figure 5 shows an imposed limitation the students were presented with, requiring

them to create a form using only the revolve tools before then being challenged with exploded views, sub-assemblies, and assembly tasks for the first time.

3 METHODS

To enhance the CAD skills of PD students, the PD academic team delivered an accelerated 2D/3D engineering CAD syllabus focused on core competencies within first year by providing a learning program focussed on SolidWorks. This teaching block of 2D/3D engineering CAD, utilizing SolidWorks, was delivered in week two of the first-year PD students higher education journey. Sixty-Two BSc PD first year students undertook eight 1.5-2-hour sessions over the course of a 15-hour accelerated synchronous teaching block during a single week. CAD Bash synchronous teaching was also supported by asynchronous content in the form of pre-recorded videos and prepared worksheets/guides. Students receive 6 hours of taught content on Monday, 1.5 hours on Tuesday, 1.5 hours on Wednesday, 4 hours on Thursday and 2 hours on Friday.

Prior to commencing 'CAD Bash', each student completed a Pre-CAD Bash skills audit using a 5-point Likert Scale approach delivered through Microsoft Forms. The questions asked were designed to ascertain the student cohorts' current knowledge/understanding of software programs, situated within Engineering CAD, such as SolidWorks as well as exploring general CAD competencies. Historical data was also collected to ascertain prior knowledge on CAD software in addition to demographic data. This survey helped inform the tutors on student prior knowledge allowing adjustments to the level of learning/content delivered. A Post-CAD Bash skills audit was then collected using the same 5-point Likert Scale approach delivered through Microsoft Forms. This data provided insight into the effectiveness of the accelerated teaching block, thus informing CAD tuition for the remainder of the academic year. Student feedback and the findings from CAD Bash was ultimately collected to demonstrate the effectiveness and impact of an accelerated CAD teaching block focused on fundamental engineering CAD competencies. Fifty-two students completed the pre and post CAD Bash survey (response rate of 83.4%); a summary of the key results and findings are presented in section 4.

4 RESULTS & FINDINGS

As demonstrated in Figures 6 and 7, CAD Bash has elevated student core competencies and CAD proficiency significantly within five days. Notably, 92.3% of students agree or strongly agreed with the fact they are confident in using the SolidWorks interface, with no negative responses provided.

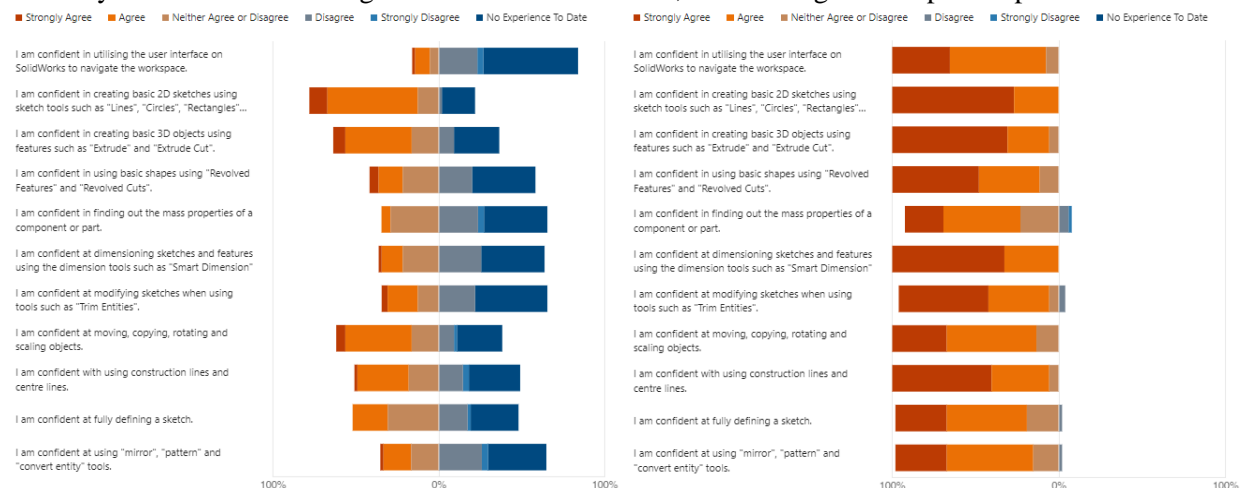


Figure 6. Sketch Tools: Pre CAD Bash-Skills Audit (Left); Post CAD Bash-Skill Audit (Right)

Within the core sketch competencies/commands all areas drastically improved, and of note only a few students still had negative responses to the skills audit questions regarding specific features (mass properties: 7.7%; trim tools: 3.8%, sketch definition: 1.9% and mirror, pattern and convert entity tools: 1.9%). In the use of the more advanced tools most students made significant progress, however with more complex features tools such as lofts (19.2%), sweeps (21.2%) and editing bodies (i.e., splits, combine: 19.2%) felt that they needed more support/tuition on this. A small number of students highlighted the need for some additional support on hole wizard (5.8%), technical drawings (7.7%) and assemblies (7.7%).

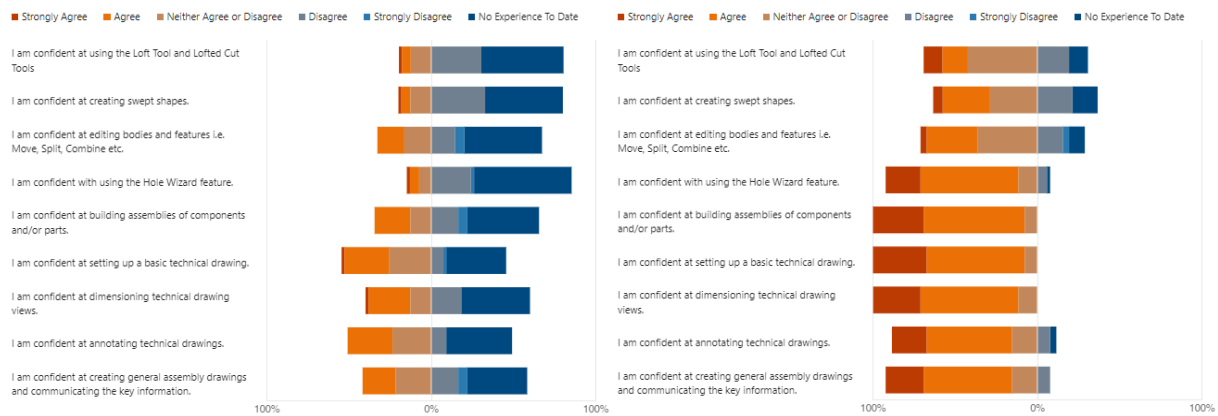


Figure 7. Features & Outputs: Pre CAD Bash-Skills Audit (Left); Post CAD Bash-Skill Audit (Right)

The overall rating of CAD Bash for the week was 4.54/5 with all but two respondents providing a 4-or-5-star rating for their rating of the CAD Bash experience. Limited negative feedback was provided; a few comments regarding hardware/software issues experienced early on and students noting the speed of certain sessions being a little fast for them. Overall, the development and deployment of CAD Bash was a huge success with the vast majority of feedback from students being overwhelmingly positive:

Overall, it was a great experience in order to help to understand the fundamentals of CAD (P2)

In my opinion, CAD Bash was taught very well and has definitely made me more confident while using SolidWorks. I didn't really see any negatives. (P23)

5 CONCLUSIONS & RECCOMENDATIONS

From the feedback small changes are necessary such as providing further resources to those students who excelled/completed the sessions quicker than expected. No demographic or nationality issues were noted; international students identified that the videos with captions and handouts helped with any confusion around terminology. Logistically CAD Bash is a significant challenge to organize, however we are currently exploring how we can use the CAD Bash model for other software. We also aim to explore how more complex modelling tools such as ‘Lofts’ and ‘Sweeps’ can be better integrated into CAD Bash. The deployment of CAD Bash demonstrated how the delivery of an entire term’s worth of CAD tuition within a single week prepared students better for future CAD learning but also created room within the CAD syllabus to teach more complex classes. This has enhanced our entire three-year CAD syllabus for PD students, positively impacting student skill level. Enhanced CAD skills delivered in an accelerated syllabus also offers increased placement/graduate opportunities too. Furthermore, a larger proportion of the cohort compared with previous years have since acquired Certified SolidWorks Associate status with a small number also achieving Certified SolidWorks Professional status.

REFERENCES

- [1] Asperl A. How to teach CAD. *Computer-Aided Design and Applications*. 2005 Jan 1,2(1-4),459-68.
- [2] Sung K. and Rowan N. CAD Education Curricula in Product Design: The Case of De Montfort University, UK. 2018, CAD Solutions, LLC.
- [3] Parhusip B. R., Saputra T. W. and Ayaki I. M. Implementation of Project Based Learning by SolidWorks Application in Online Learning during the COVID-19 Pandemic. *American Journal of Educational Research*. 2021., 9(7), 431-434.
- [4] Gonzalez R. *Method to Accelerate Student Proficiency in CSWP/CSWPA Solidworks Certification Exams and Fusee Mechanism Profile Analysis, 2022*, (Doctoral dissertation, University of Idaho).
- [5] Khiati S. CAD and 3D Visualization software in design education: is one package enough. *Journal of Engineering & Applied Sciences*. 2011, 3(2), 91-100.
- [6] Watkins M., Casamayor J. L., Ramirez M., Moreno M., Faludi J. and Pigozzo D. C. Sustainable product design education: current practice. *She Ji: The Journal of Design, Economics, and Innovation*. 2021 Dec 1, 7(4), 611-37.
- [7] Ottway J. R. and Webster R. An investigation into the value and benefits of the SOLIDWORKS certification program. In *ASEE Annual Conference & Exposition 2019 Jun 15*.