Title:
CAD Education Curricula in Product Design: The Case of De Montfort University, UK

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Introduction:
Computer Aided Design (CAD) has become one of the essential parts of design education (especially product design) in higher education (HE) [2], [19]. Although CAD can be defined broadly as the use of computer systems (i.e. hardware and software to perform specialized design functions) to assist in the creation, modification, analysis or optimization of a design [9], it is often used to refer to the process in which mathematically precise geometrical descriptions of physical objects can be created [7], [15]. CAD education in HE, therefore, typically entails teaching parametric modelling software programmes such as SolidWorks, SolidEdge, TFlex or BricsCAD [11]. Such software programmes enable (product) design students and practitioners to translate sketches into precise CAD models that can be refined, developed and tested in a virtual environment and generate fully-defined technical drawings for global manufacture. As the use of CAD reduces the amount of physical model making (e.g. in order to produce a working representation of a semi-final product) for decision making in industrial design process, CAD increases production efficiency (by reducing resources and therefore cost) from the industrial and market-driven standpoint [5]. Proficiency in CAD, therefore, is required especially for product design graduates to be employable (by meeting industry-level design expectations that emphasise production). British Industrial Design Association's (BIDA) student employability survey in 2017 also emphasised that CAD abilities is one of the key aspects that recruiters are looking for (along with good design process, sketching, strong sensitivity for user experience, CMF – colour, material and finishing – and latest trends and technologies) [4].

Despite such importance, research on CAD education in HE in the context of product development is still in its infant stage. The existing research has focused predominantly on theoretical discussions and high-level suggestions for CAD education in HE (e.g. from CAD education towards CAx education, frameworks for general support, role of CAD in training engineers, strategies for the transition to CAD-based education) [1], [5-7], [18-19]. Relatively little attention has been paid to practical implementation of CAD education. Even when practical implementation experiences in actual courses were described, the studies were based mostly on mechanical engineering [3], [16]. Reports on the implemented CAD education curricula from product design perspectives are largely missing. This paper, therefore, aims to provide one such case in order to provide the status quo of CAD education curricula in product design in the UK.

Main Idea:
The selected case is from product design programmes (BA and BSc) in the school of design at De Montfort University (DMU). DMU is one of top-rated universities in terms of student employability in industrial (or product) design. It was rated third after Loughborough University and Brunel University according to the BIDA (British Industrial Design Association) student employability survey in 2017 [12]. DMU provides very strong product design programmes which have been accredited by the Institution of Engineering Designers (IED) with the renowned, excellent outcomes and exemplary

resources and handbooks [10]. DMU product design programmes have four consecutive CAD modules (equivalent to courses in the USA and Canada) for the first two years (three-year degree programmes) (Tab. 1).

Year	*Term*	*Module code*	*Module title*
1	1	DESP1001	CAD for Product Designers 1
	2	DESP1002	Digital Outputs for Product Designers 1
2	1	DESP2001	CAD for Product Designers 2
	2	DESP2002	Digital Outputs for Product Designers 2

Tab. 1: List of CAD modules in product design programmes (BA and BSc) at DMU.

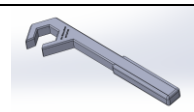
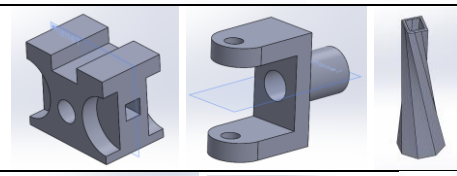
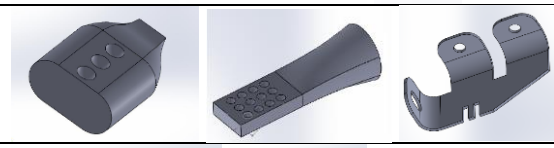
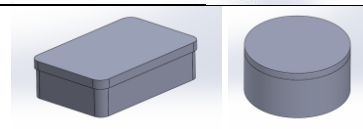
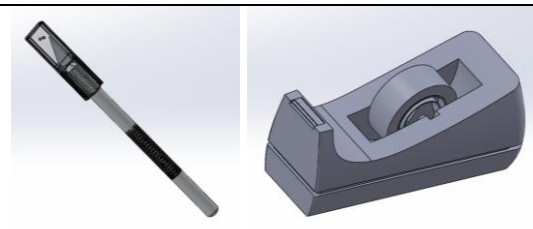
Two modules in the first year (DESP1001 and DESP1002) teach students about basic solid modelling and assembly, reverse engineering, technical drawing with British Standard (BS), compelling rendering and simple animation through structured learning activities. The ones in the second year (DESP2001 and DESP2002) allow students to learn about advanced modelling (e.g. surface modelling and internal detailing for injection moulding) and assembly, complex technical drawing with BS, compelling rendering and advanced animation, through independent, self-directed study. All four modules utilise SolidWorks (for modelling, assembly and technical drawing) and KeyShot (for rendering and animation). They are based mostly on active learning [13] with a series of dry-run exercises and projects. Each module has one-hour lecture and two hour practical (CAD session) per week as teaching and learning activities. Lectures introduce new terms (e.g. orthographic projections) and projects, and explain concepts and principles behind the practice (e.g. BS8888). CAD sessions provide students with design/project briefs and/or 2D drawings with dimensions of various shapes such that students could create appropriate 3D models, technical drawings and/or renders (both still images and animation) based on them. Projects are usually introduced during the first lecture in order to show the clear links between module learning outcomes, exercises and projects (for assessment). Tab. 2 shows module schedule for DESP1001 and Tab. 3 shows exercises and projects for DESP1001 as an example.

Week	*Lecture*	*CAD session*	*Activity*
2	Introduction (to the module, projects, SolidWorks, parametric modelling)	Introduction to SolidWorks, 2D sketch and extrude (dry-run 01)	Project 1
3	Engineering drawing 1 (orthographic projections, lines, sectioning, hatching)	Revolve, sweep and shell (dry-run 02)	Project 1
4	Engineering drawing 2 (advanced sectioning and dimensioning)	Loft and mirror (dry-run 03)	Project 1
5	-	Pattern and fillet (dry-run 04)	Project 1
6	-	Assembly (dry-run 05)	Project 1
7	-	Project support	Project 1
8	Engineering drawing 3 (advanced dimensioning)	Project support	Hand in
9	Creating a compelling product render	Introduction to KeyShot	Project 2
10	-	Project support	Project 2
11	Wrap-up of the module	Project support	Hand in

Tab. 2: Module schedule for DESP1001: CAD for Product Designers 1.

During the CAD sessions, tutors use a combination of demonstration videos, written instructions, live demonstrations, and one-to-one feedback and support for universal design for learning [14]. With the availability of tutor's assistance, CAD sessions rely mostly on students' learning by doing [8]. All exercises and projects are individual tasks yet students are encouraged to help/teach each other during the CAD sessions as part of peer learning [17]. All projects in each module are for summative assessment yet CAD sessions for project support (1 or 2 sessions before submission) provide students with formative feedback and practical help. Assessment in the first year is done by a tutor whereas the one in the second year is done by students and moderated by a tutor. This is to enable students to

develop abilities to evaluate others' work and critically reflect on their own practice in the advanced CAD modules.

Activity	*Description*	*Example photos*
Dry run 01	Spanner design (2D sketch and extrude)	
Dry run 02	2D drawing to 3D model (revolve and shell) and paper clip design (sweep)	
Dry run 03	2D drawing to 3D model (mirror) and vase design (loft)	
Dry run 04	2D drawing to 3D model (pattern and fillet)	
Dry run 05	Box design (assembly)	
Project 1	Reverse engineer a common household stationary product with a minimum of four parts; create parts by appropriate sketching and modelling; and assemble parts as accurately as possible	
Project 2	Create a photo-realistic render of a model and make a presentation board (using the modelling files from the Project 1)	

Tab. 3: CAD session activities in DESP1001: CAD for Product Designers 1.

Module level feedbacks for all four CAD modules have been mostly positive with constructive suggestions. For example, according to the module level feedback for DESP1002 in 2017/18, the majority of responded students were satisfied with lectures (58.8%), CAD sessions (88.2%), Project 1 (modelling and technical drawing) (88.2%), Project 2 (rendering and animation) (64.7%), written instructions (94.1%) and demonstration videos (58.8%). They found Project 1 (100%), Project 2 (100%), CAD sessions (88.3%) and written instructions (76.4%) particularly important to achieve module learning outcomes (MLOs)[1] comparing to lectures (47.1%) and demonstration videos (41.1%). The answers for the perceived difficulty levels of teaching and learning activities mostly showed normal distribution. Suggestions for improvement included less lectures and more tutorial exercises per day (as some advanced students completed them too early).

Conclusions:

This paper reviewed literature on CAD education and identified the knowledge gap in providing practical implementation of actual courses for CAD education from product design perspectives. The aim of the paper, therefore, was to provide one such case from De Montfort University (DMU) in the UK. The paper provided an overview of the CAD education curricula with some examples in product design programmes at DMU focusing on active learning activities. The importance of and satisfaction on active learning (with projects and CAD sessions) were highlighted by students' module level feedback. This paper expanded our understanding of the status quo of product design CAD education (in the UK). The practical implication is that any future attempts to (re)design CAD modules in HE (in the UK and beyond) could be informed by this paper.

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[1] Module learning outcomes of DESP1002 are as follows. On successful completion of this module, students will be able to: a) translate 2D orthographic data into 3D models; b) demonstrate the ability to generate accurate and appropriate 3D geometry using CAD software for a relatively complex product; c) demonstrate the ability to produce realistic visual renders (both still images and animation) using appropriate software; and d) demonstrate the ability to product accurate technical drawings to the relevant British Standard (BS8888).

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