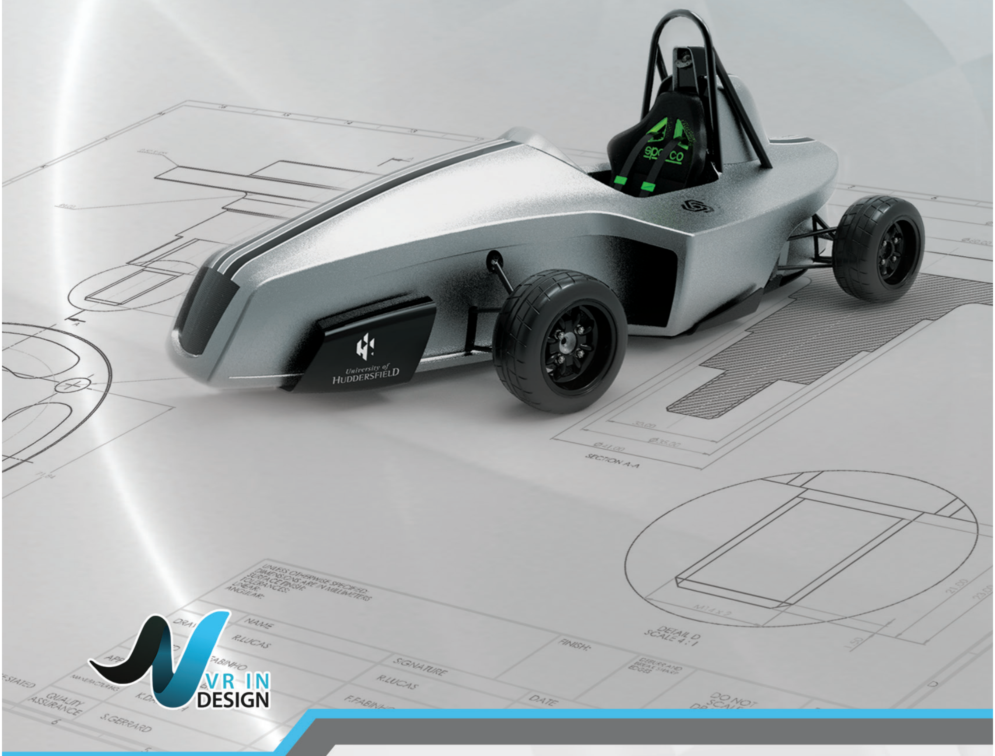
VR/AR in Design

A GUIDE TO INTERACTIVE TECHNICAL DRAWING FOR ENGINEERS AND DESIGNERS.



VR IN DESIGN

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VR/AR in Design

A GUIDE TO INTERACTIVE TECHNICAL DRAWING FOR ENGINEERS AND DESIGNERS

AUTHORS

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2019

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Foreword

Technical drawing is the most important element of communication between employees in engineering fields. To avoid communication difficulties it is essential that both the author and reader of the drawing know the correct rules. To achieve this goal, students must learn these drawing conventions during their training, and the part or the assembled product must be visualised in the correct 3D form. With the use of virtual and augmented reality products developed in this project, a measurable performance increase will be achieved in learning technical drawing rules and standards. Additionally, the use of these products in Engineering and Design education is expected to provide added value by minimizing the error rate found in technical drawings in industry.

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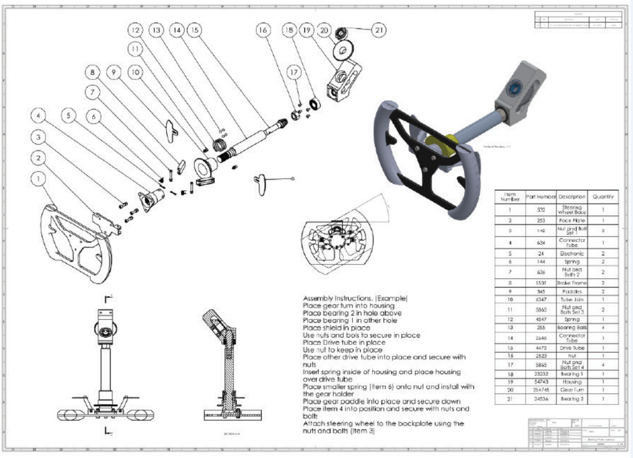
Introduction

Technical Drawings (TD) must fully define the properties required to produce a designed item. These drawings form the contractual instrument in the transformation of a design into a physical reality. As a legal instrument, TD's must conform to rules and conventions, which protect both the designer and manufacturer from liability by clearly and fully representing all the instructions needed to make the components. The manufacturer can demand payment for their work, provided they have followed the specifications of the drawing, if however, the resulting part is wrong it will be the fault of the designer who produced the TD. Therefore, clarity and precision in TD are essential skills for all designers and engineers.

There are concerns from Higher Education (HE) institutions and industry about the decline in standards of TD due to the lack of understanding of basic principles and conventions that underpin the best practices. The purpose of this catalogue is to showcase the use of simulations/animations along with augmented and virtual reality (AR/VR) technologies to improve learners' engagement, competence and skills; especially when compared to traditional didactic methods in the context of higher education settings.

The tools and methods illustrated in the catalogue were developed in response to the findings of a previous international study covering industry's perceptions and expectations of TD education in comparison to the knowledge and skills of graduates from design and engineering degree pathways.

TECHNICAL DRAWING

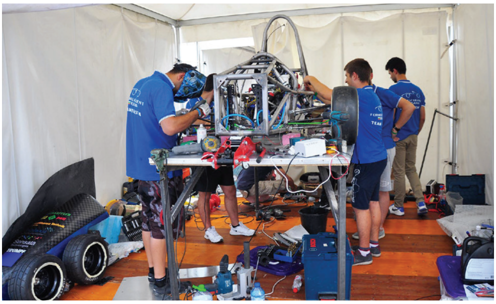


Assembly drawing.

TD's have always been an essential component in the formative education of new engineers and product designers (E&D). They play an important role in communicating the technical product specifications (TPS) (i.e. material, size, shape, tolerances) for manufacturing during the new product development process.

The decline in standards due to the lack of understanding of basic principles and the conventions of drafting skills that underpin these practices represent a challenge for HE institutions and traditional teaching strategies. Despite product design students being known to prefer visual, sensing, inductive, and active learning styles; most engineering education and in particular the teaching of technical drawing skills has relied on auditory, abstract, deductive, passive, and sequential teaching styles.

The introduction and broadening of 3D tools as a key teaching component in the design process has significantly changed the teaching of TD related subjects. However, HE institutions are still left with the challenge of developing new T&L tools and methods to ensure that students acquire the knowledge and skills in TD required to meet the demands of both academia and industry.



Formula Student team.

TD is regulated by a number of internationally recognised rules and conventions that transcend language boundaries, for example, International Standards Organisation (ISO128) and European Norms (EN) ensure conformity between national standards such as British Standard (BS8888) or the American National Standards Institute (ANSI). The globalisation of manufacture and design has made TD a particularly suitable topic for teaching developments using visually rich (and language light) teaching technologies. The resulting international initiative is a partnership between collaborating institutions in Turkey, Bulgaria and the United Kingdom with funding from the European Union. The project explores and tests the boundaries of the technology to facilitate teaching and learning in Technical Drawing (TD) in Design and Engineering Education.

Content planning.

VR & AR

According to the widely adopted definition, Virtual Reality (VR) represents a high-end human-computer interface that involves real-time simulation and interactions through multiple sensorial channels[1].

Unlike traditional user interfaces, instead of only viewing a screen, the users of the Virtual Reality are put ("immersed") inside an artificially created and computer simulated convincing interactive environment and can experience it through all their sensorial channels such as vision, hearing, touch, even smell in a way that mimics the real life.

Although Virtual Reality is not a new as technology having its roots already in the stereoscopic viewers of 19. Century, it is still stumbling through roller coaster-like hype cycles. This is only beginning to show its potential with a new generation of end-user hardware devices and software applications. Virtual Reality is not just a medium or an entertainment tool, but it provides already applications for solving real problems in the field of architecture, engineering and design, medicine, etc. and very soon will be an indispensable tool in education and engineering routines.

Unlike Virtual Reality, which provides immersion in an entirely virtual environment, Augmented Reality (AR) is an interactive experience of exiting natural environment, where the real

world objects are enhanced using digitally produced perceptual overlays. Sensors, cameras and special algorithms recognize the observed objects and determine their position and orientation, the end-user device then renders the graphics or texts superimposing these over a user's view of the real world. This augmentation is happening in real time and within the context of the physically existing environment. Now, the users are able to interact and to manipulate digitally this additional information layer in real time.

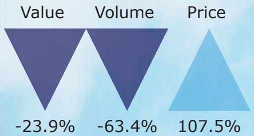
Applications of Augmented Reality can be either as simple as just a text notification or as complicated as instructions on how to use a highly complex equipment. Augmentation of the environment can highlight specific features and processes, enhance understandings and provide timely information. Nowadays, the main devices, which are widely used for running AR applications, are the smartphones and the tablet computers. AR technology is still emerging, but according to the analysts is highly promising to disrupt the everyday life and to act as an "on-call co-pilot" to the physical environment and interactions of the people, which will have significant implications on the industry, education, healthcare, entertainment etc.

The considerations for the student/teacher for this project were:

- VR headset (HTC Vive and Samsung Gear)
- Competency of modelling SolidWorks or equivalent
- Experience in design for manufacture and in technical drawing skills
- Some experience using AR and VR
- Mobile Phone (Android 7.0+)
- Powerful computer

1. Burdea, G. C., & Coiffet, P. (2003). Virtual reality technology. John Wiley & Sons.

AR/VR IN DESIGN



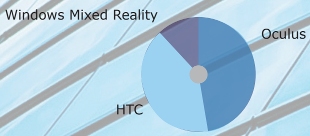
The market for VR has stalled in the past year. Due to the fall in prices of VR headsets in 2017, the market size grew considerably.

Apple CEO Tim Cook stated "I'm incredibly exited by AR because I can see uses for it everywhere. I can see uses for it in education, in consumers, in entertainment, in sports. I can see it in every business that I know anything about"

Since 2017, VR headsets have generally stayed at the same price which has led to a smaller market size.

Pokémon Go sparked an interest in AR games, with 22% of smartphone owners stating they had tried an AR game.

Mintel Group Ltd is the world's leading market intelligence agency. Recent Mintel reports provide a useful prediction for growth and development within this sector of technology. This data has informed the choice of hardware platforms and systems used by the collaborative teams to develop content and research the educational benefits at a relatively early stage in the introduction of these technologies.



A survey from steam states that Oculus and HTC own roughly 90% of the VR headset market.

There is a mainstream appeal for information based AR across all generations.

45% of all ages are likely to use information based AR, compared to 27% for AR games.

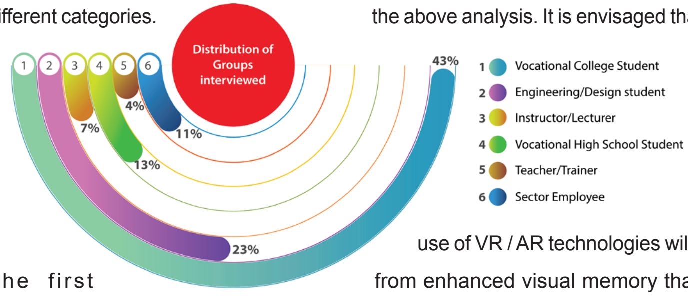
Currently, 7% of the UK have used VR mobile apps with this continuing to rise.

Currently, 8% of the UK have used AR mobile apps with this continuing to rise.

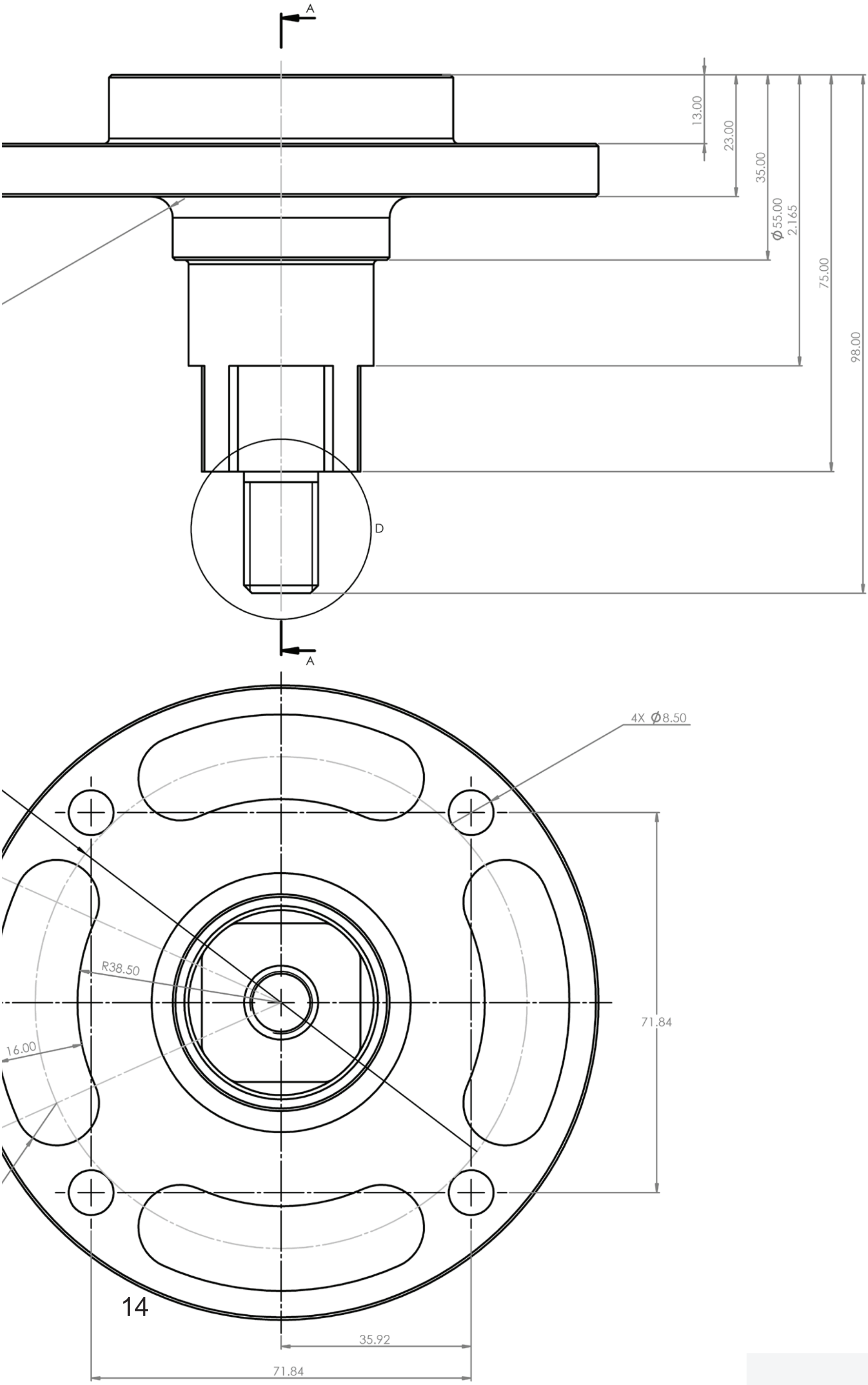
The global market for both VR and AR is expected to grow considerably in the next few years. With the global market expected to rise to $192.7B by 2022.

Needs Analysis

The results of an international needs analysis study conducted to determine the requirements of teaching principle concepts used in manufacturing and assembly drawings are evaluated. Particularly, in order to form an infrastructure for new teaching methods, supported by VR / AR applications. Initially, the stakeholders were identified, parameters and methods were determined. An online survey with 320 participants was carried out by a team of researchers in Turkey, Bulgaria and UK. The survey addresses three different categories.



The first category covers Perception of Technical Drawing Education, second category assesses Technical Drawing Knowledge and Ability, finally third category covers Expectations about Technical Drawing Education. This study resulted in different analyses which constitutes an important database in terms of the number of participants, the participant diversity and also the origin country with many sub- analyses not given in the above findings. The variation of differentiation on schools and professions has generated important data for use in the content and material development phases. Research showed that there is an important deficit in all stakeholder groups and countries that cannot be covered by known methods, which could be assisted in the field of Technical Drawing Education. The outcome of this research was used for the development of VR/AR content of the technical drawing training programme that is compatible with the priority topics in the above analysis. It is envisaged that the use of VR / AR technologies will gain from enhanced visual memory that will contribute to measurable improvements in learning performance. This will be tested by comparison of future TD output with that of previous learner cohorts. A further refinement to measurement of the efficacy of the technology to can be provided by recording and subsequent analysis of the number of hits on any given subject area of the online content.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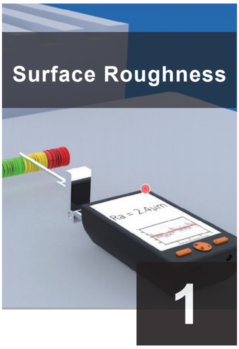
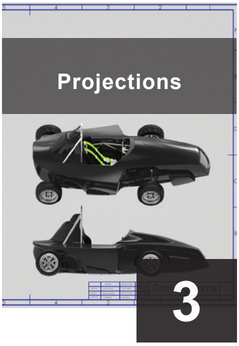
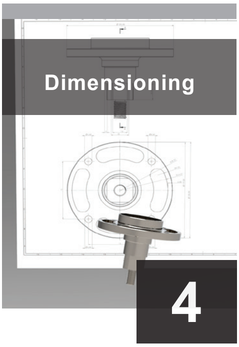
Case Studies

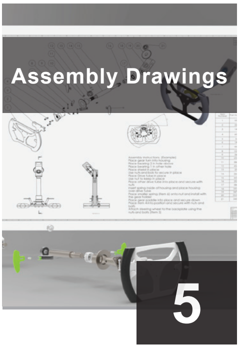
As a result of these analyses, the topics grouped according to priority order. The subjects and grouped modules are listed in order of priority according to the need analysis results as shown below:

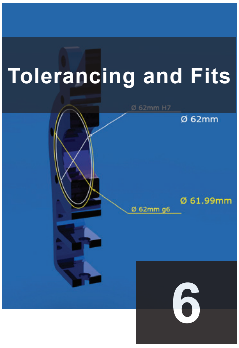
1. Geometric measurement and dimensional tolerances
2. Surface Treatment Markings/Surface Roughness
3. Dimensional Tolerances, Edge Tolerances, Shaft and Hole Tolerances
4. Sectioning and Projections and Perspective
5. Dimensioning and Tolerances
6. Working and assembly drawings











Case Study 1

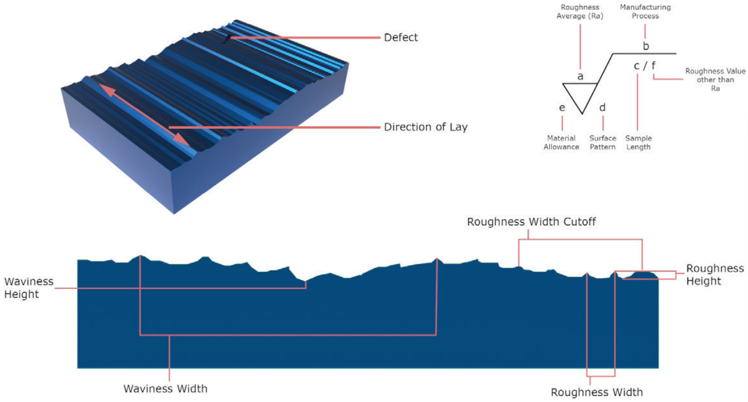
Surface Roughness

Surface roughness is a part of surface texture. It is calculated through the direction of a normal vector of an actual surface from its ideal form. If the deviations are small the surface roughness would be smooth; if the deviations are large then the surface roughness would be rough. Roughness can be considered to be the high-frequency, short-wavelength component of a measured surface. It is necessary to know both the amplitude and frequency of a surface in practice to know whether it would be fit for a purpose.

Specification Details

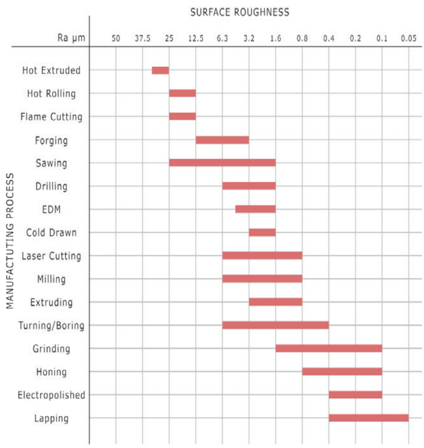
Learner made aware of specification details and the importance about accuracy.

Different manufacturing methods can produce different values of surface roughness. As stated before, the better the surface roughness, the more expensive it will be to produce.



Capture from Roughness animation.

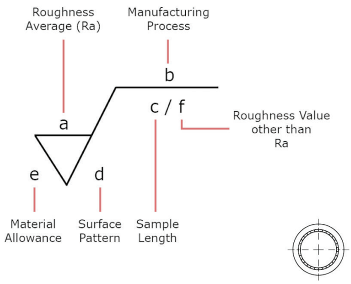
It is necessary to have the proper specification of finish as it is required for the function of the surface. Specification of surface finish should only be used when needed as the cost of the finished surface increases drastically as the quality increases. Surface roughness is for minute imperfections.

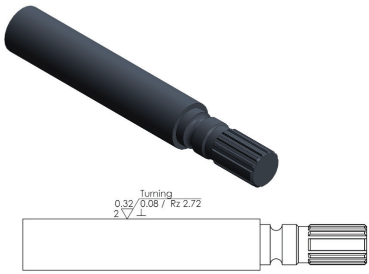


Surface roughness vs. manufacturing process.

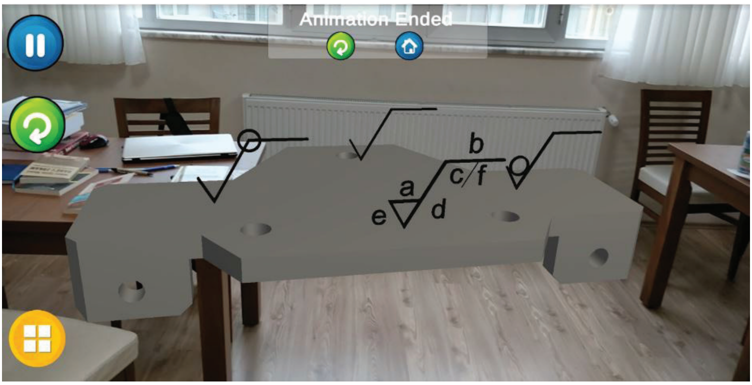
Presentation Methods

In this section of the project the subject matter referenced alphanumerical data in the form of tables and specification symbols. The strategy has been to introduce the topics and raise a general awareness of their influences on the finished qualities of the manufactured component.



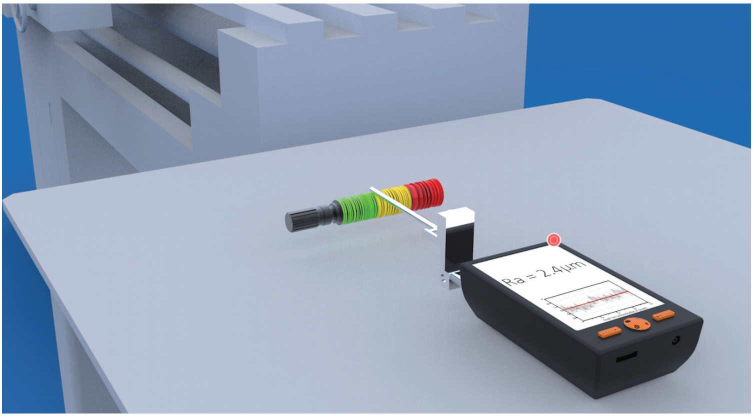


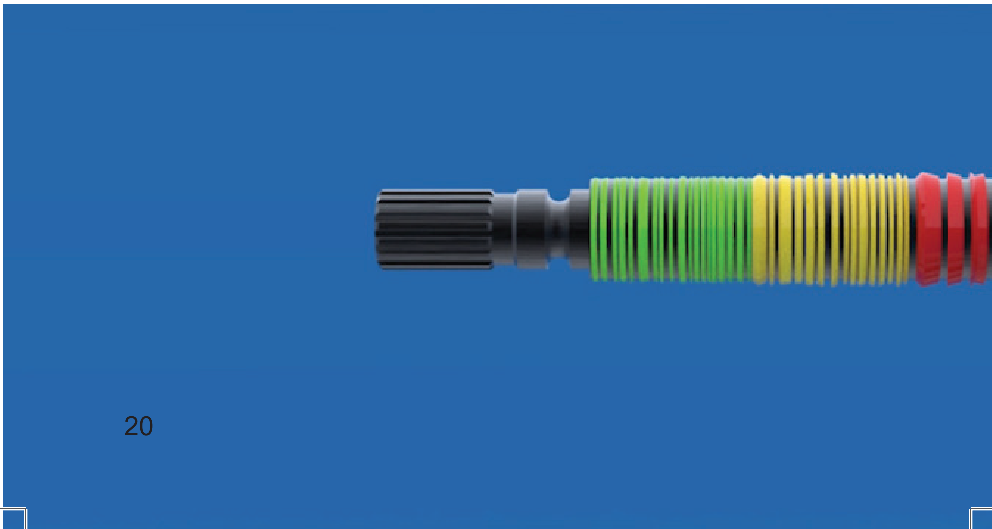
The shape of the symbol will have an impact on how the surface finish is achieved. Using a circle within the symbol will tell the manufacturer not to remove any material. A closed triangle will show that material will be removed and an open triangle can have any manufacturing process used.



Animation

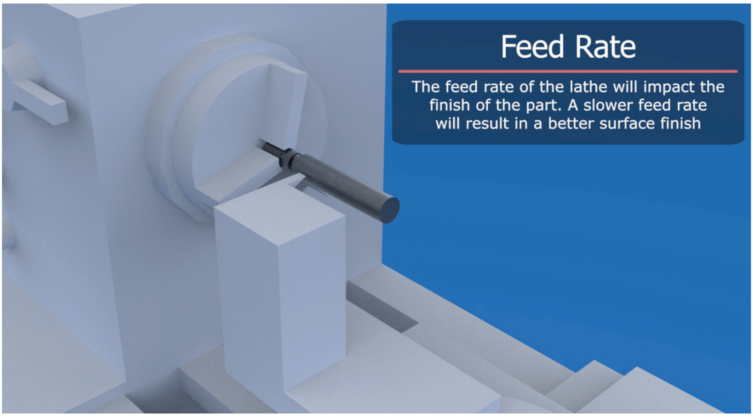
Animations along with AR and VR technologies can improve engagement, competence, and skills. Animations allow learning through interaction, they visualize real world situations enhancing the understanding about a problem and its context. The animation contextualises the manufacturing implications of surface finishes by illustrating different surface qualities, how they are achieved and how they are measured.

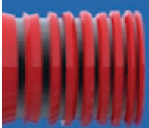




The use of audio

Audio has been used to determine the minimum time the on-screen text should be shown to enable the learner to assimilate the information. It is anticipated that most users will repeat sections to consolidate their understanding of the topics. In addition, classical music has been overlaid to filter out possibly distracting background sound in the learning environment.





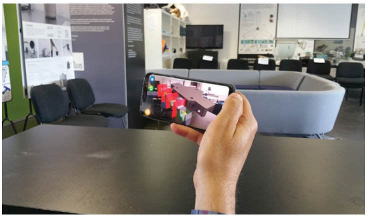
The different surface roughness grades have been exaggerated with the different colours. Fast – Medium – Slow (Feed rate) Red – Yellow – Green respectively.

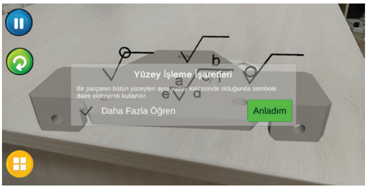
A surface roughness tester would be able to measure the surface roughness of the part to ensure that the part is within specification. The tester can automatically calculate different roughness values depending on which method is needed. Graphs can be created and exported onto a computer to be looked at in more depth.

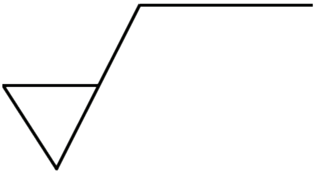
AR

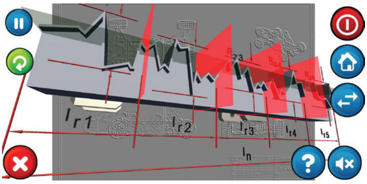
Augmented reality gives the learner more freedom to explore the effects of surface finish on the product.

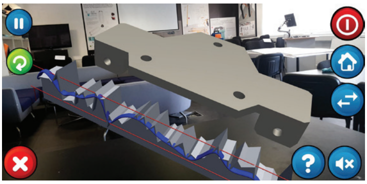
This is an important aspect of learning, which allows the user to pause, explore and consider the implications of surface finishing. The sense of participation rather than passive presentation is a valuable addition to teaching a complex technical subject.









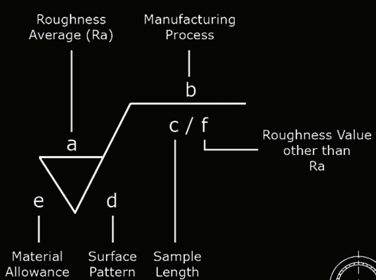


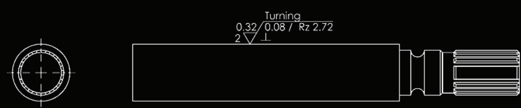
Surface finishing symbols are important as they are used to describe whether or not material removal by machining is required and other related specifications or parameters.

Commentary

The animation is intended to give the learner a fast introduction to the subject, with sub-topics that can be accessed later to reinforce understanding via the phone app. The expectation is that learners should become aware of the text-based information on surface finishes and the implications of specification on the final manufactured component. The speed of the presentation is designed for brevity and frequent replay until the content is mastered. It would be unlikely that learners would to attempt to memorise specification tables via this medium, however, the intention is that users will become familiar with the need for accurate surface specification and will subsequently access print-based tables with greater confidence.

AR is well suited to this topic. Users can interact with the component by zooming in on detail. An overlay of information on the component and the ability to rotate the part enables the user to develop a meaningful understanding of the significance of surface roughness in relation to adjacent parts or surfaces. The phone camera has enormous potential to facilitate the exploration of a real component in real time with its augmented version on screen.



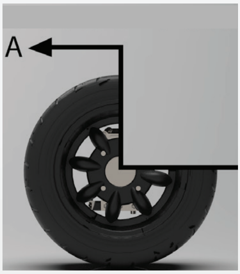


Case Study 2

Sectioning

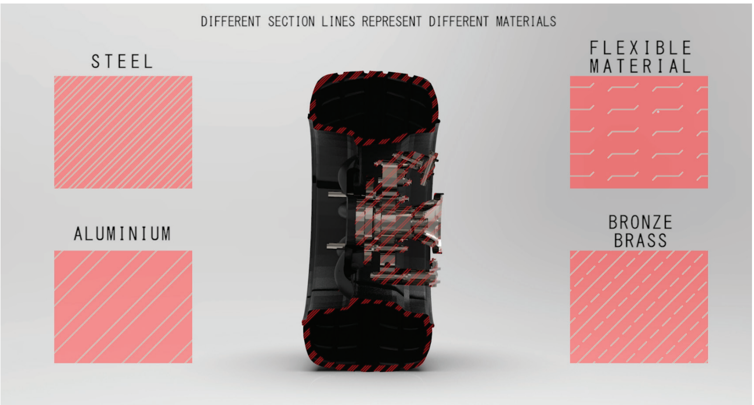
Sectioning shows a part being dissected by a cutting plane. Once dissected the internal construction of the part is shown. Cross hatching is used to show where the solid surfaces are when cut.

A section is a cut through an object to reveal detail that is hidden inside the part or assembly. The point at which the object is cut is known as the cutting plane. The direction of the view of the hidden detail (the section) is indicated by arrows on the orthographic views. There are a number of types of section, which the learner should understand and use to communicate data on any given component. Examples of the animation content are shown.



The purpose of the animation is to encourage the student to become familiar with sectioning strategies used to convey meaningful data as clearly and succinctly as possible. Moving imagery is particularly effective as a means of illustrating the transition from orthographic view to sections.

Sectioning

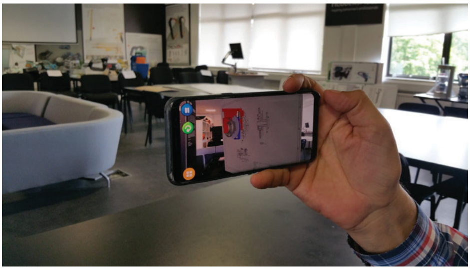


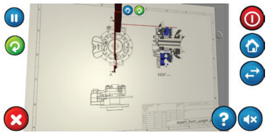
In this A-A section it is shown the hidden detail of the part. Materials are designated by patterns of hatched lines that are defined by international standards.

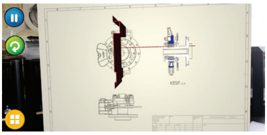
In this example the hidden detail has rotational symmetry, therefore, a half section cut will show all the detail inside the part.

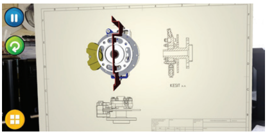
Sectioning AR

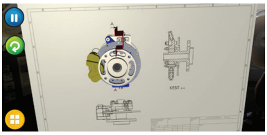
Selection of images showing sections in AR

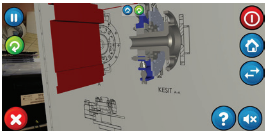


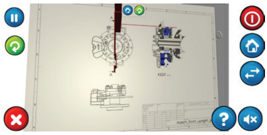


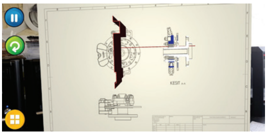




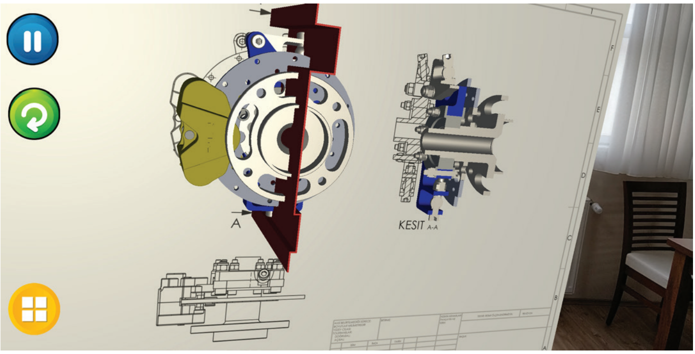


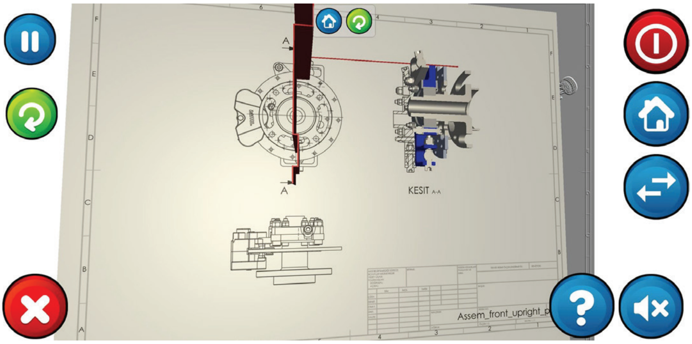


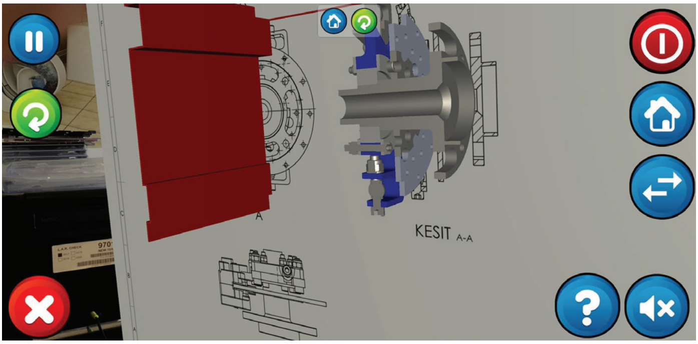




Potential for showing physical objects behind AR will allow the user to explore and understand hidden sectional details



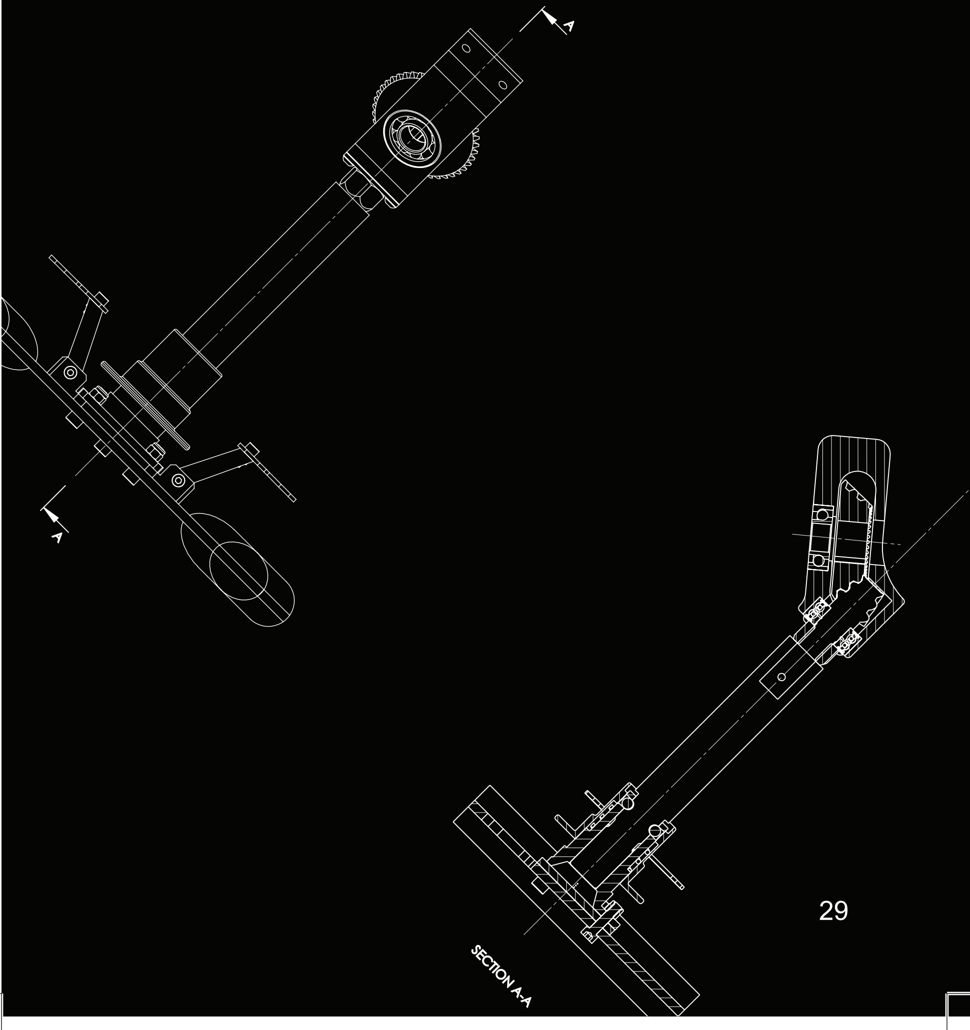




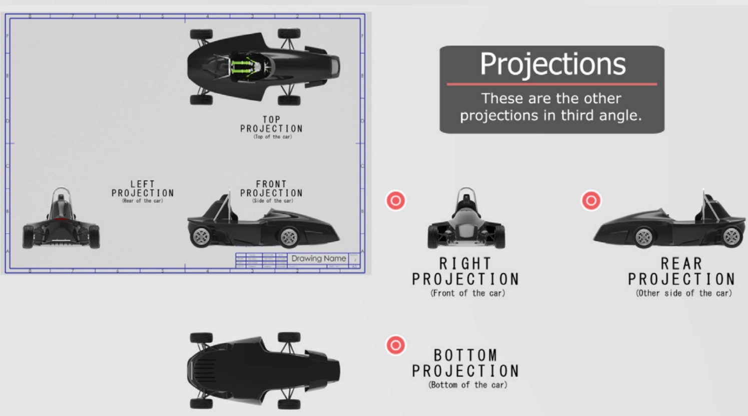
In these AR examples, a section is cut to show hidden detail inside the part. This is called the "cutting plane" (in red).

Commentary

The advantage of moving images, taking the learner from solid 3D form to 2D hidden detail, needs little explanation. In a book or on TD's the student by must infer the relationship between the orthographic and sectional representation of the object. AR and VR enable the learner to interact with the topic and explore the relationships between orthographic views and the hidden detail shown in sections. With practice this becomes second nature to a professional but these media allow a much more efficient transfer of knowledge and understanding.




University of
HUDDERSFIELD

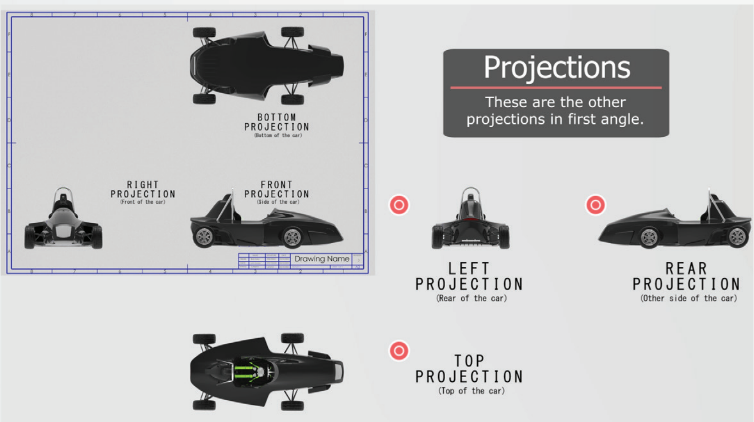

TOP
PROJECTION
(Top of the car)
LEFT
PROJECTION
(Rear of the car)
FRONT
PROJECTION
(Side of the car)
Drawing Name
Projections
These are the other
projections in third angle.
RIGHT
PROJECTION
(Front of the car)
REAR
PROJECTION
(Other side of the car)
BOTTOM
PROJECTION
(Bottom of the car)

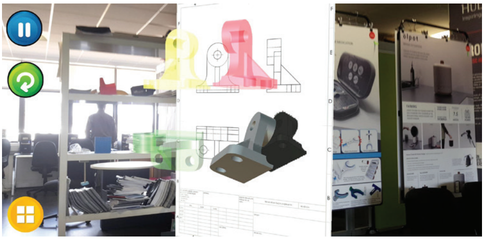
Case Study 3

Projections

Projections are used to represent three-dimensional objects in two-dimensions by projecting the image on a planar surface. Projections can show different views of an object to make the object easier to understand. The different views also mean dimensioning and consequently manufacture can be achieved to a high quality.

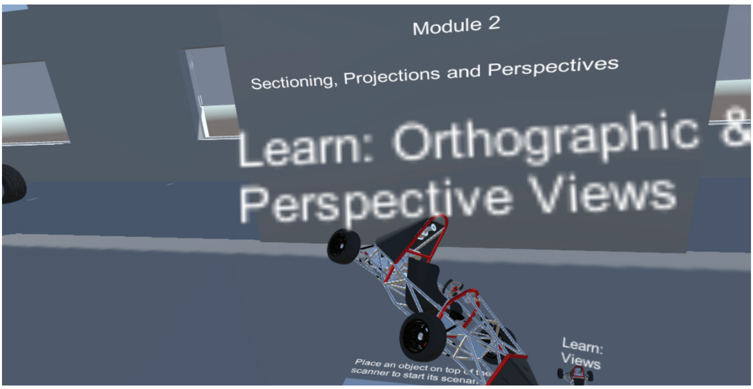
Incorrect projections are shown first in a less appealing render to split the animation into 2 parts. A less memorable part (Incorrect section) and a more memorable part (Correct section). Showing an incorrect version allows the student to see what most people would do and how to correct it. All projections are shown with the ones being used in context of the drawing. This would show that the other views could be used.





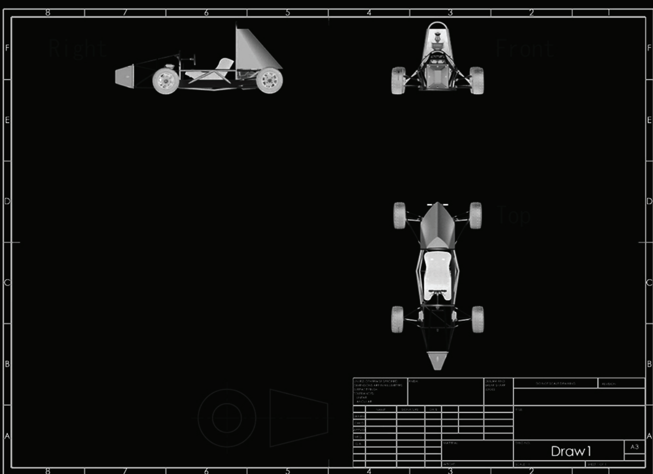
AR shows the same information in a more interactive context. It is anticipated that students will self-select the medium that best suits their individual learning style. The variety of presentation platforms for the same teaching objectives will enable more effective learning, reinforcement and retention of the key points within the topic. In particular the mobile phone camera has the potential to be used to relate a 3D view of the component, which can be simultaneously explored in AR.

Further AR development of orthographic projections would be an advantage for students who have had little or no previous experience of technical drawing. Although this would be desirable the team judged the greater need was for AR support in understanding sections.



Commentary

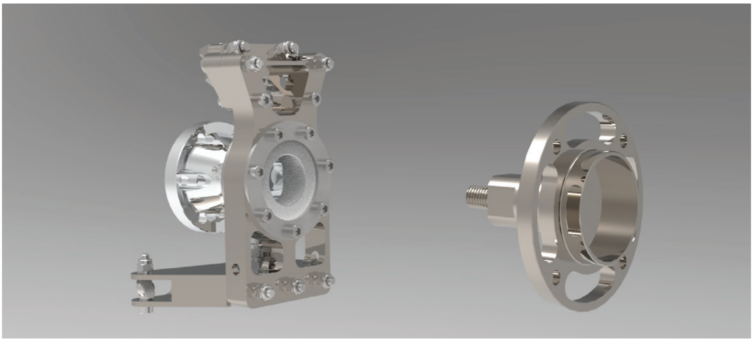
The difference between first and third angle projections can be confusing for students in the first stages of TD training. However, in recent years the use of CAD software has greatly facilitated the transfer of 3D designs into a 2D orthographic format, which enables students to see and interpret the content of orthographic views. The animation addresses the problem by showing students both correct and incorrect projections to help them to understand the importance of adherence to TD rules and conventions. This is a more common problem for design students who have less exposure within their curriculum to the disciplines of TD. It will also be useful for engineering students in the first stages of mastering orthographic projections. After testing the animation with Product Design students and observing user behaviours, a final iteration of the animation was made that included more supplementary orthographic views. These are now presented at a slower pace to reduce the number of times that students had to pause to process the information, which they found distracting. A final reinforcement was added to the animation at the request of the trial user group showing a fade between first and third angle to highlight the differences in how the views are organised on the sheet.



Case Study 4

Dimensioning

Dimensioning is used for giving size and positions. It is a numerical value that is shown with appropriate units of measurement. It is used to outline the size, form, orientation, location, or other geometric characteristics of a part.

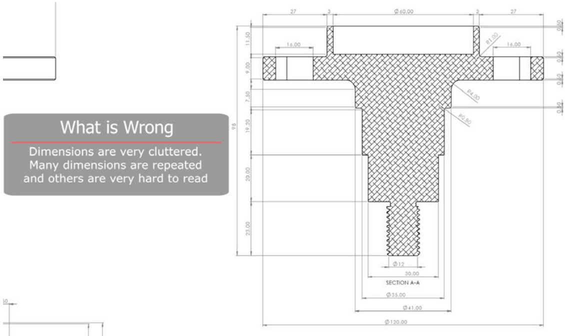


Dimensioning

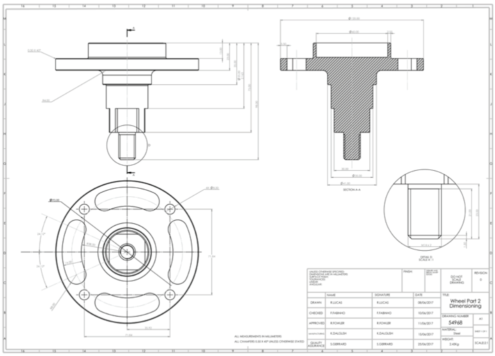
Case study content - Dimensioning lines, arrows and numbers. Guide lines and special marks. Dimensioning systems and types (parallel, angular, chained, offset, using coordinates, combined with the help of charts). Placement of dimensions in manufacturing and assembly drawings. Special dimensions, auxiliary dimensions, absolute dimensions etc.

What is covered. Standards for dimensioning and how to conform with them.

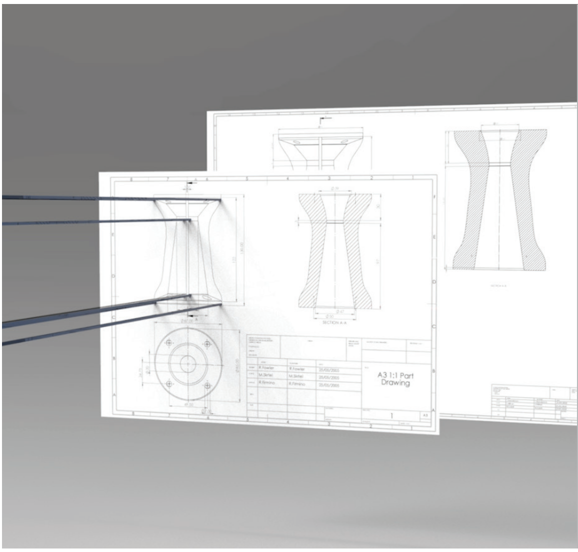
Baseline, Threads, symbols, shapes..., line types, title block , revision tables.



Incorrect drawing on left

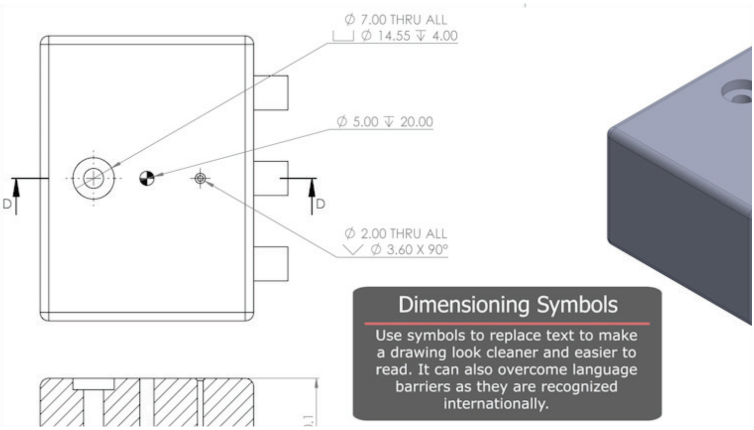


Corrected drawing on right



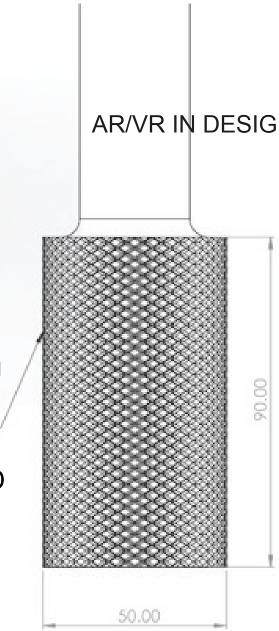
The combination of a 2D concept in drawings and 3D realisation in animation facilitates a deeper understanding of the relationship between them. Scale is explored and illustrated by the transformation of a 1:1 scale animation to the drawing plane in TD on which other scales such as 2:1 or 1:2 can be seen.

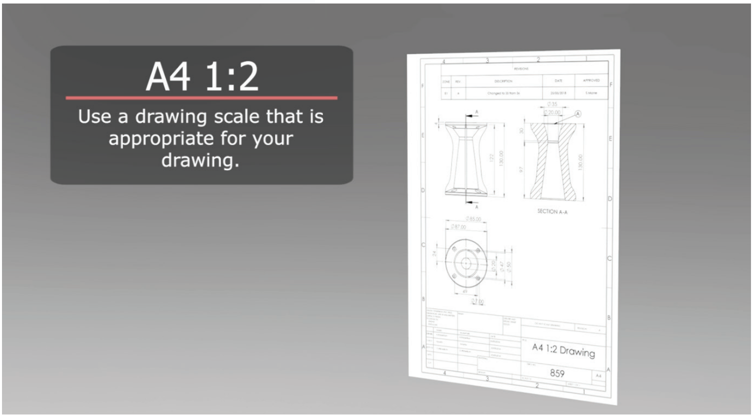
This section of the project introduces the learner to a number of text based conventions used in technical drawings. Recent developments in CAD systems have specific regulations on how symbols and dimensions should be shown on 3D projections. However in both 2D and 3D formats the same basic requirements for consistency and accuracy remain as an essential element of the learning experience.



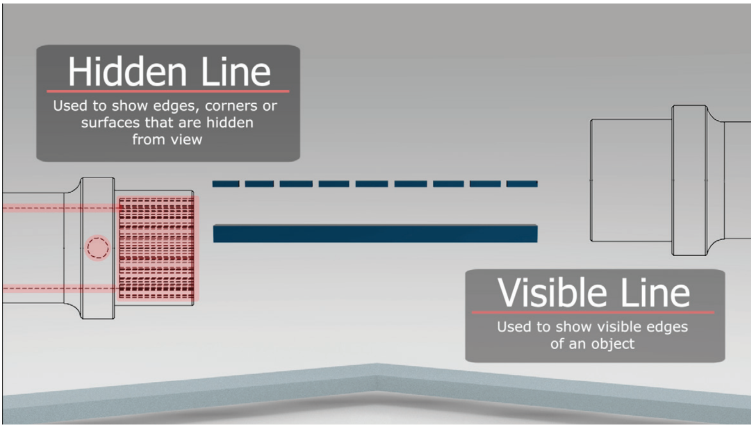
In these illustrations taken from the animated course, the user is presented with a fast and efficient introduction to information that will be required in order to produce the item accurately.

Dimensioning covers a large number of different conventions that have been presented in separate topic sections of the animation with the intention that learners will reference these points later during the production of their own technical drawings. This is also a useful technique for editing the animation itself, which should facilitate updates and additions to the presentation as TD conventions are amended.

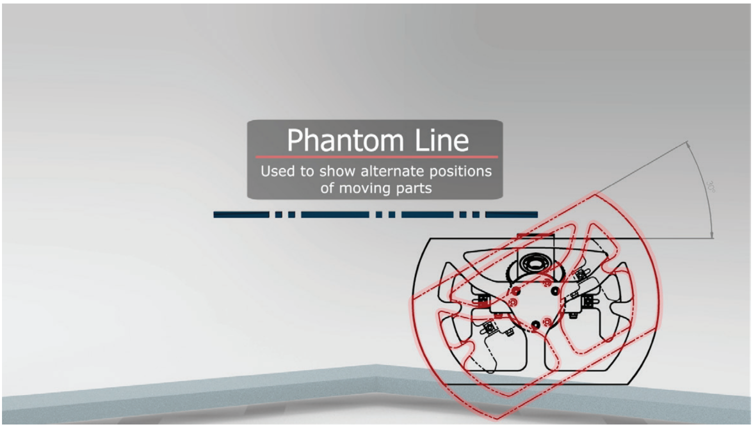




Knurling is used to improve grip of the part. The pitch of the knurl, type of knurls and length of area is needed to dimension the part properly.



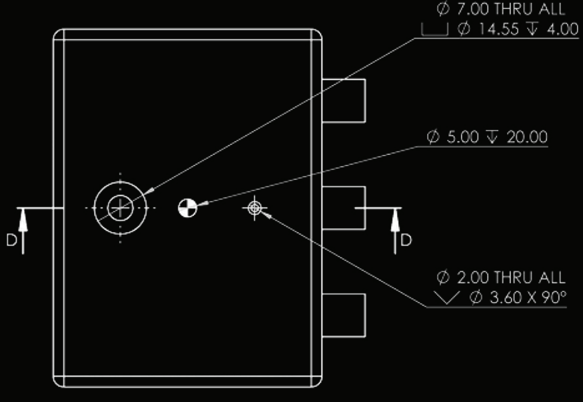
Line types in technical drawing are very important, for example hidden lines are used to show edges, corners or surfaces that are hidden from view. They are represented as short dashed lines. Visible lines are used to show the lines that are not hidden from view. They are shown as continuous lines.



Another example of how line types are used is the Phantom line, this line is used to show alternate positions of moving parts. They are shown as alternate long and double dashed thin lines.

Commentary

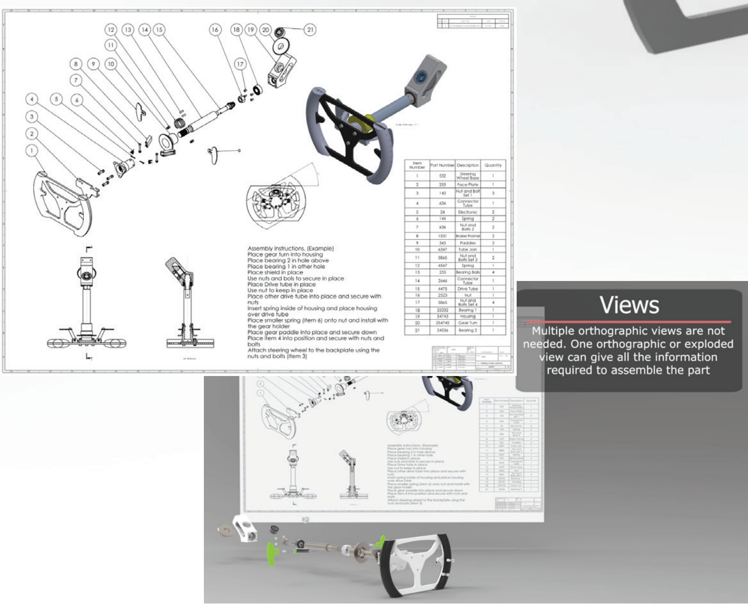
The animation is visually rich, however it should be recognised that dimensioning is a text based process which is essentially a 2D convention, but with clear 3D implications! Because dimensions are essentially alphanumeric data, they are easily accommodated in print in the form of textbooks. However, experience has shown teachers that students are often reluctant to look for printed reference when so much data is available electronically. The animation addresses this by breaking down the topic into a series of subsections designed to give a quick introduction to the main conventions used in dimensioning. Thus this time-based medium becomes an alternative source of data to the learner that can be used for reference as the student consolidates their knowledge of the topic through practice and repetition.



Case Study

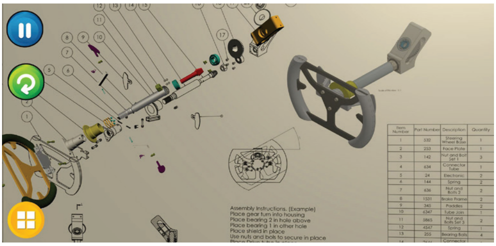
Assembly Drawings

Assembly is when a component which includes a number of parts and often sub-assemblies are put together to perform a specific function whilst also being able to be disassembled without damage. In many products what could be an assembly at one point could be a sub-assembly at another point.



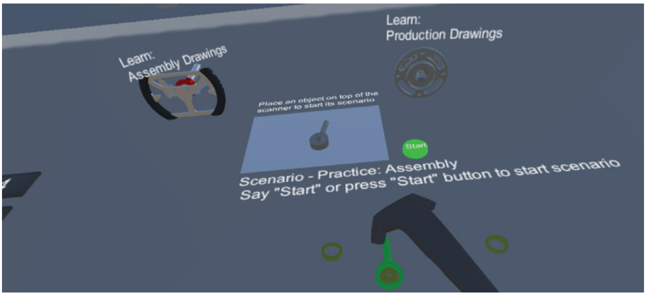
The animation explains a variety of types of assembly drawing to help the learner familiarise themselves with the ways in which this type of drawing is used in the manufacture and assembly process. Greater context is given by using the steering wheel assembly to illustrate the relevance of assemblies and to explain general rules and conventions for layout and annotation.

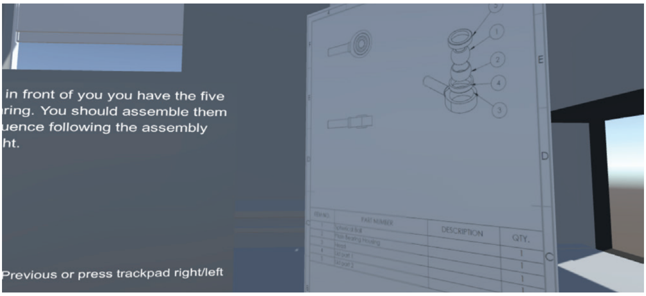
AR shows similar content to the animation. As with other AR presentations, this offers the learner an alternative platform to access the information in a format that best suits their learning preference.



This experience will be much enhanced by learners who have access to the actual steering wheel assembly, which can be captured by their mobile phone camera. This should afford students a fully tactile and interactive learning experience.

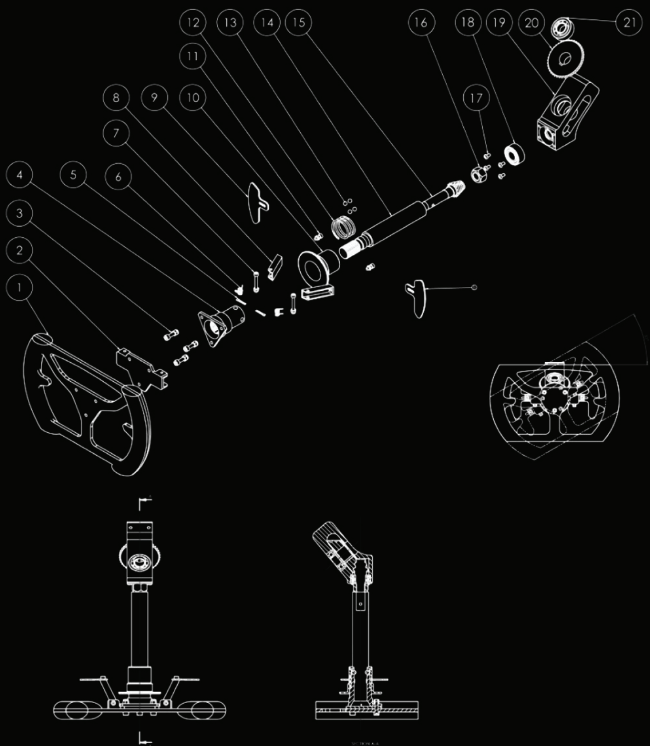
VR presents an assembly drawing and invites the user to assemble the virtual parts in the correct order using the drawing for guidance. The screenshots below illustrate some of this content. As this is an interactive platform it enables the learner to test and perfect their understanding of the assembly process. The facility to test and consolidate knowledge through VR enables the learner to take full responsibility for mastering the content of the presentation, which frees up the teacher or trainer's time to deal with other aspects of learning.





Commentary

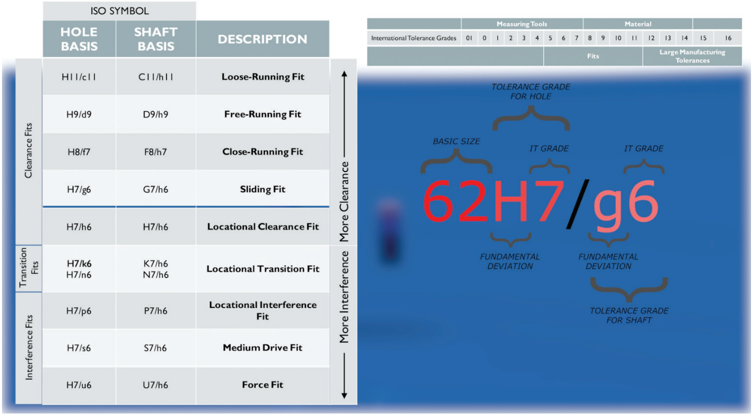
This case study offers the team an opportunity to assess all three forms of digital presentation. It is visually rich and therefore much better suited to knowledge transfer systems that use time based media. It also enables students to identify ways in which information can be effectively communicated to other participants in the process of transferring a design to a manufactured reality. Although this may not have been the initial objective of the study it is without doubt a positive outcome for both the teacher and the student.



Case Study 6

Tolerancing and Fits

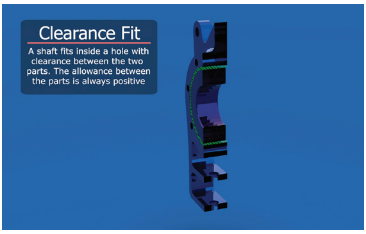
TOLERANCING specifies the maximum allowable variation of an actual part from the stated dimension. It is an important aspect of Technical Drawing because it specifies and controls the precise fit of components within an assembly to ensure the parts can be assembled and function as intended.



	ISO SYMBOL		
	HOLE BASIS	SHAFT BASIS	DESCRIPTION
Clearance Fits	H11/c11	C11/h11	Loose-Running Fit
	H9/d9	D9/h9	Free-Running Fit
	H8/f7	F8/h7	Close-Running Fit
	H7/g6	G7/h6	Sliding Fit
	H7/h6	H7/h6	Locational Clearance Fit
Transition Fits	H7/k6 H7/n6	K7/h6 N7/h6	Locational Transition Fit
Interference Fits	H7/p6	P7/h6	Locational Interference Fit
	H7/s6	S7/h6	Medium Drive Fit
	H7/u6	U7/h6	Force Fit

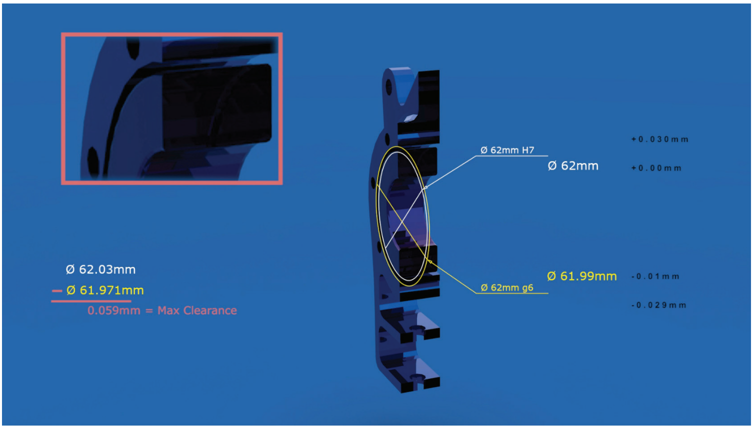
	Measuring Tools								Material								
International Tolerance Grades	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
							Fits							Large Manufacturing Tolerances				

The animation presents a number of terms and conventions relating to tolerance and fit. Much of this is text-based rules and conventions that must be understood by repeated reference to each sub-topic. The learner is therefore given a rapid introduction to the subject materials in the expectation that they will return to the animation to master the level of detail required by their curriculum. The



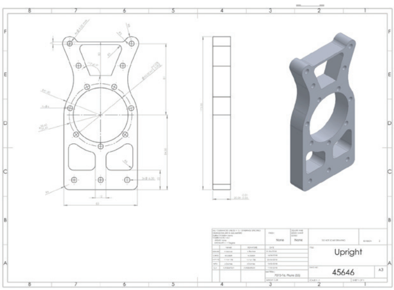
FIT describes the basic terms used to define the relationships between components.

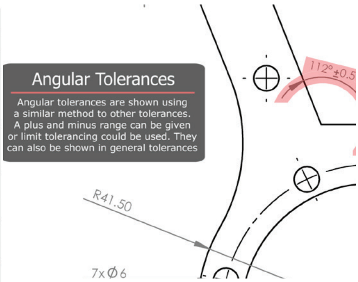
animation introduces tolerancing and explains how this relates to a variety of definitions of fit. It goes on to explore how this impacts on manufacturing decisions such as selective assembly with the intention of illustrating to the learner the importance of accurate specification in the design stages to achieve the best economic and performance outcomes for the component in production.



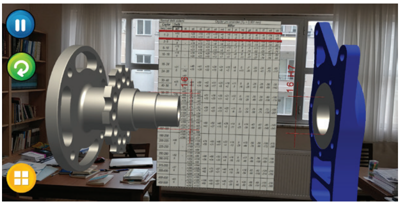
The effect of fit and tolerancing to produce the best manufacturing results at minimum cost is explored in this chapter. Learners should have an awareness of how these variables interact upon one another and have a good understanding of the definitions of various fits.

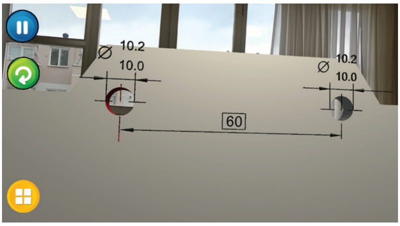
Animation split into two parts. Fits and then tolerance. There is overlap between both. Again, is easier to refer back to later on.



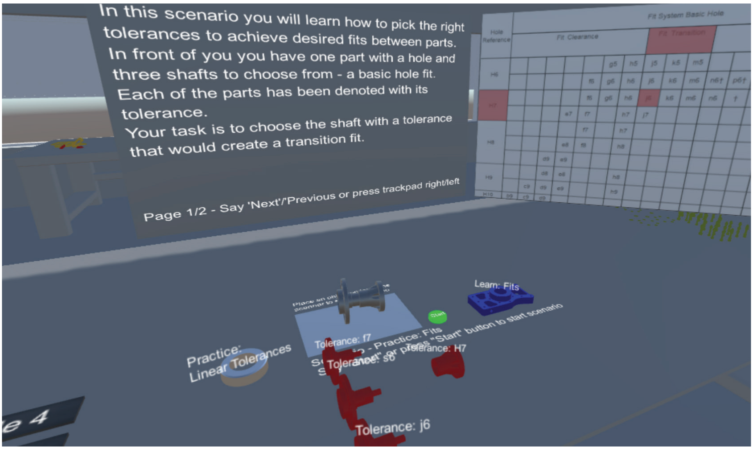


AR offers more interactive learning by showing the tabulated information in the background at the same time as the fit is illustrated in 3D. The presentation highlights the interconnectivity of tolerance specification and manufacturing considerations, which facilitates a richer understanding by the learner.



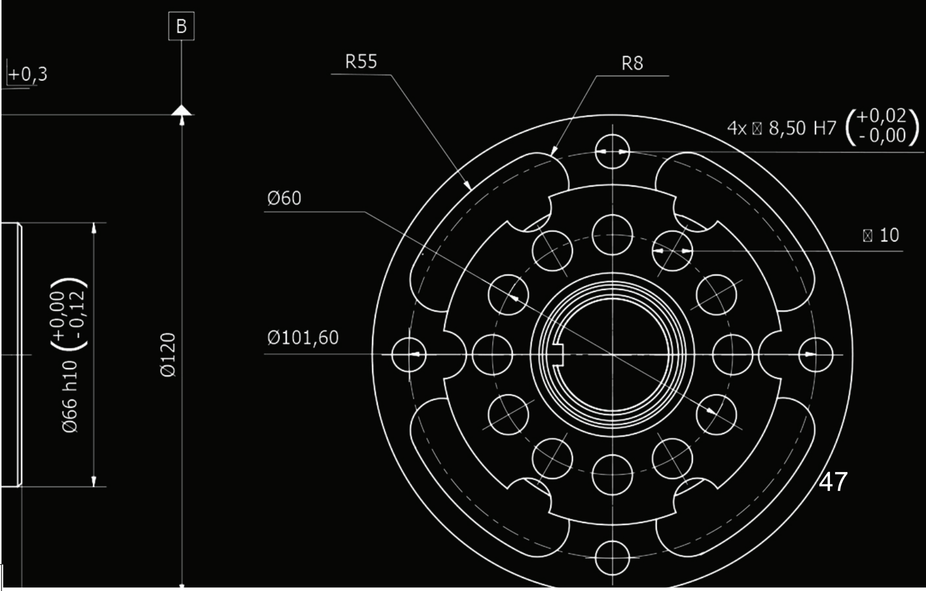


VR enables the teacher to devolve responsibility for testing knowledge acquisition to the student. The content assumes some prior learning has taken place and tests for understanding by inviting the student to pick the correct tolerances to achieve the required fit. Learners can check their understanding and return to the animation and AR as often as necessary until the topic has been satisfactorily mastered.



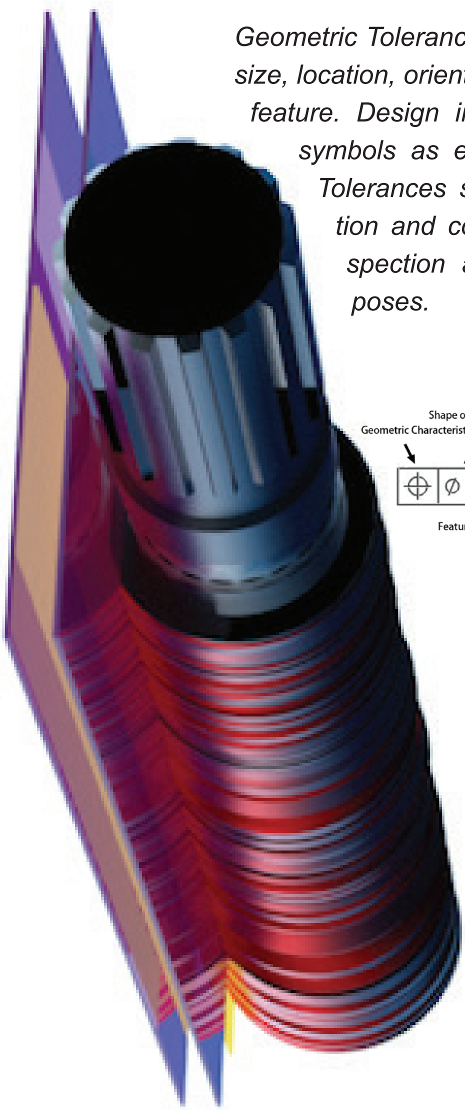
Commentary

All three digital forms of presentation have been employed in delivering the topic. Once again this will provide an excellent opportunity to the teaching team to record and research how learners have used all three formats. It also enables learners to become familiar with these tools as a means of communicating complex issues to key members of both manufacturing and design teams using digital platforms, which will become more common in the future.

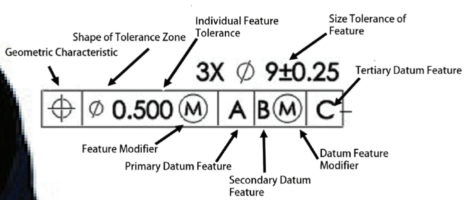


Case Study 7

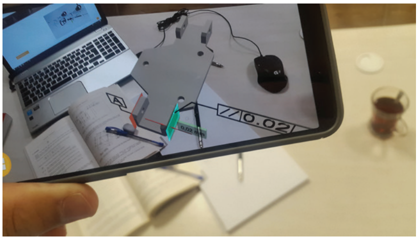
Geometric Tolerancing

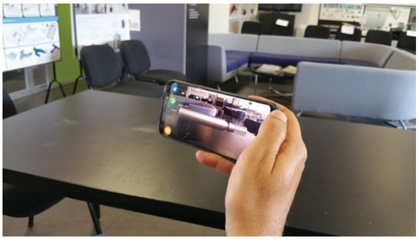


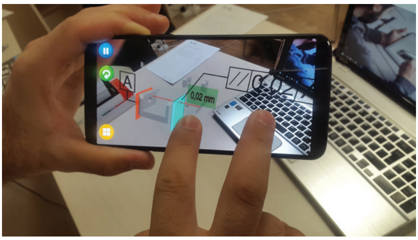
Geometric Tolerancing is used to define the size, location, orientation, and form of a part feature. Design intent is shown through symbols as effective communication. Tolerances show the allowed variation and coordinate system for inspection and manufacturing purposes.



AR is the primary platform for delivery of this content. The topic is visually rich which is well suited to the interactive potential of AR. The images shown here illustrate the learner exploring the effects of geometric tolerance on a product in relation to the specification symbols for the manufacture of the component. As with much of the content it is designed to raise awareness and ensure a grasp of first principles. The learner would be expected to use printed reference for tolerance tables until through repetition they acquire a suitable grasp of the topic.

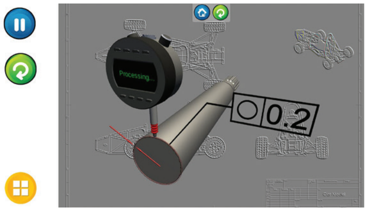


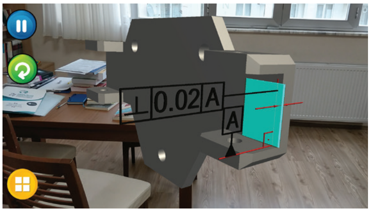


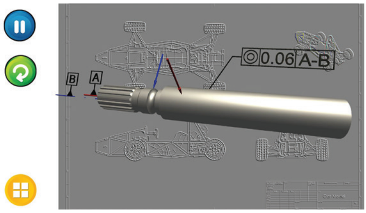


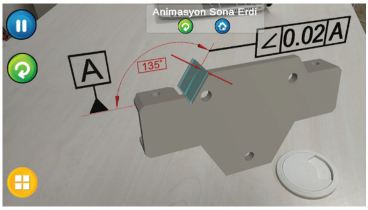
Term	Symbol
diameter	∅
spherical dia	s∅
max material cond	Ⓜ
least material cond	Ⓛ
projected tol zone	Ⓟ
free state	Ⓕ
tangent plane	Ⓣ
statistical tolerance	⟨ST⟩

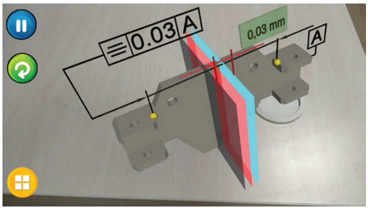
The animation introduces the learner to the symbols used in geometric tolerances. It can be introduced before or after the AR presentation to suit the learner's needs. In either case it is anticipated that the content should be revisited as often as necessary to ensure an adequate understanding is achieved.



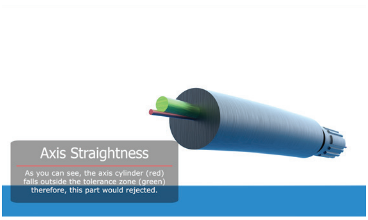


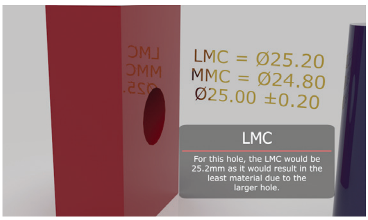






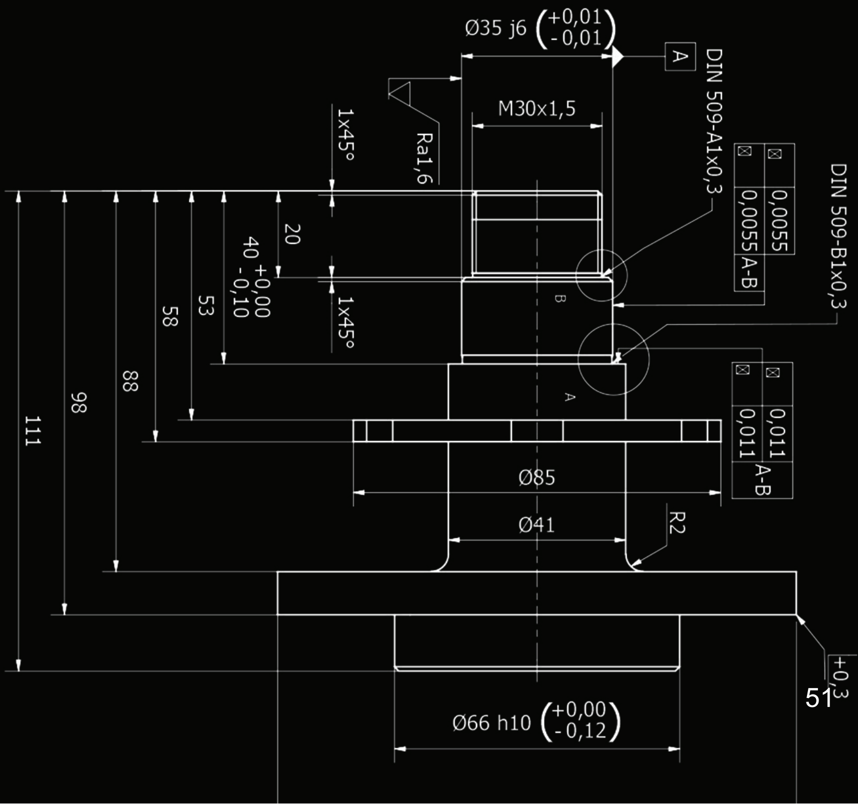
Concepts such as Maximum Material Condition (MMC) and Least Material Condition (LMC) are briefly presented within the animation to raise awareness of this volumetric approach to defining tolerance within components. Parts are shown within and outside tolerance to illustrate the consequences and to explain when a part would be rejected. A technical drawing is also shown to give some context around the module.





Commentary

AR is very effective in this context. The material presented is at a level of specification detail that would be outside the curriculum of most Product Design courses but is essential knowledge for engineers. However, it is very valuable for all designers to be aware of the implications of geometric tolerances within the manufacture of any part. In all cases we anticipate that learners will use the digital presentations as an introduction to the topic and will make further reference to printed materials to master the detail of specification commensurate with their chosen discipline.



Initial Training Evaluation

Measurement of success

The aim of this study is to investigate the effect of a specific mobile AR application on the cognitive learning levels of students' to increase learning performance on Technical Drawing. The study group consisted of students studying in the Automotive Program of the Vocational School. Experimental design with pre-test and post-test control groups were used in the study. The pilot training were delivered totally 12 hours in April 2019. The measurement of participants' success was done by pre- and post-testing. For this purpose, theoretical written examinations were set before and after training with two group. In total, the evaluation involved 30 experimental group (supported by project products as AR application and animations) and 20 control group (not supported by project products) individuals.

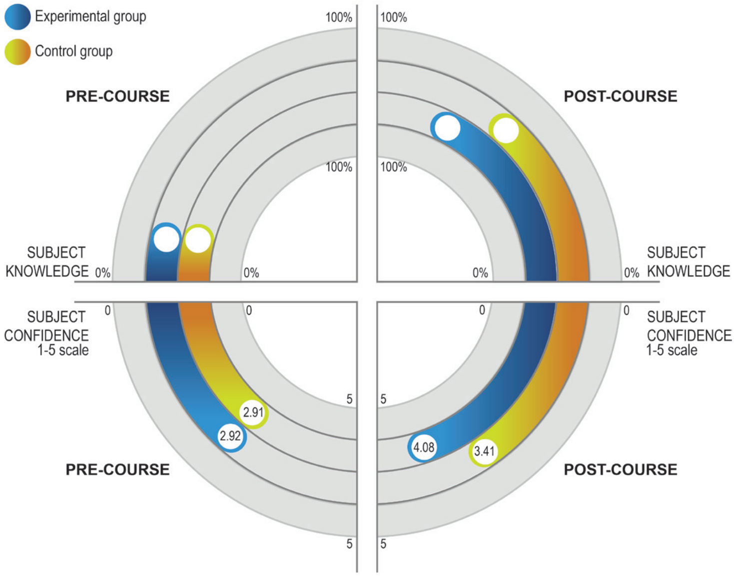
Evaluation

The comparison of the theoretical exam questioning the general technical drawing subjects given on the A4 technical drawing paper results of the pre-test – post-test study is given in Figure 1.The success rate in the final tests was 480% in the experimental group and 360% in the control group. These results indicate that the experimental group has 30% higher theoretical learning performance than the control group. The SPSS23 independent samples t-test (95% confidence interval) was used to compare the experiment and control group participant performance.

Performance Analyses

Total of 50 individuals, 30 of whom were trained supporting AR and 20 were trained without supporting AR, were evaluated. The questionnaire used for the analysis was based on a Likert scale ranging from 1 (negative) to 5 (positive). Of the 20 questions addressed to the participants, 8 questions were aimed at measuring the perception of direct technical concepts, 7 were skill and 5 were behaviour-motivation questions dealing with the contribution of the training. The SPSS23 independent samples t-test (95% confidence interval) was used to compare the experiment and control group participant performance.

The performance measurement results of the study, which consisted of 20 questions prepared in 3 sub-headings and 5-likert scale, are given in the figure below.



The pre-test results of the groups were 2.92 out of the experimental group and 2.91 as the control group. This situation, which is very close to each other, was similar in the theoretical test pre-tests. In the final tests, the experimental group results were found to be 4.08 and the control group as 3.41. The increase between pre-test and post-test was 39.7% in the experimental group and 17.2% in the control group.

These results indicate 19.6% higher learning performance in the experimental group compared to the control group. This value is very important in terms of the change in the knowledge, skills and behaviours of the participants regarding the Technical Drawing training. The study shows that the teaching using AR significantly increased the conceptual and cognitive comprehension levels.

CONCLUSIONS

This research shows that the use of AR/VR applications and animations for teaching and learning TD has an overall positive impact. This can include improved students' motivation and understanding, and hence the developed AR/VR application could be used as an effective tool to aid in the teaching and learning of TD skills for engineering and product design students.

Our pilot tests carried out through the design and development of this AR/VR application has shown that there are many aspects of AR/VR technology that still need to be explored in this relatively new area. The number of limitations found during this study regarding the use of this technology can be divided in technology, pedagogic and design and user experience limitations. Many studies concern the application of technology, but pedagogy and user experience still requires further research in the near future as technology will continue to mature and little knowledge on user experience and pedagogy influence is available.

The use of design elements (i.e. aesthetic considerations) helped in creating an improved user experience as these were perceived as usefulness, ease of use, and enjoyment. It is the view of the authors that new AR/VR applications for educational purposes should be developed from an approach where technology, pedagogy and user experience result in a holistic, well balanced methodology.

TD abstract knowledge is best suited for a virtual learning environment. However, AR is probably the best alternative as some technology limitations for VR could arise within the classroom environment. Generally, VR was not completely ideal, for visualizing and covering TD abstract and complex topics and cognitive processes. However, the sensation of immersion could be so strong, and difficult to follow by the lecturer that the pedagogic purposes could disappear and users lose all notion of interacting with the T&L system. On the other hand, AR offered a better and clear correspondence with the real world, allowing the user an active T&L experience perceived by the human senses, and still experience a rich and engaging virtual environment.

VR user interaction was more difficult than AR user interaction. VR interaction presented some problems for pursuing goals and executing actions. Therefore, a careful consideration of end-user requirements and expectations is needed to engage students. Interactivity is essential when creating AR/VR content. While animations may not have much interactivity, they can provide a visually pleasing platform to communicate TD information. AR users showed more autonomy and dynamism of user interactions, fostering a co-operative learning through collective participation. We found that using AR tools to obtain information was easier than VR. The reason might be that AR technologies are easy to operate, whereas VR requires more technical knowledge from users.

An overall positive feedback was received from the initial pilot study where selected students used the developed AR/VR and animation content. Results showed that although the users (students and lecturers) encountered technical difficulties in both AR and VR applications, they persisted with the task/objective and engaged positively in the learning process. Despite this demonstrating early results for AR/VR applications in the education of TD field the possibilities to improve the TD teaching methods and the overall T&L experience are promising. Moreover, further research should be conducted to investigate the latest and most efficient technology from the T&L point of view.

RESEARCH OUTPUTS

1. Kuş, A., Arslan, R., Unver, E., Huerta, O., Dimitrov, L., Tomov, P., Tekin, Y. “An Evaluation of Technical Drawings Training Needs For Developing New Training Methods” XXVII-th International Scientific and Technical Conference Automation of Discrete Production "ADP - 2018" 21-24 June 2018, Sozopol, Bulgaria.

2. Huerta, O., Kus, A., Unver, E., Aslan, R., Dawood, M., Kofoglu, M., & Ivanov, V. (2019, February). A Design-based Approach to Enhancing Technical Drawing Skills in Design and Engineering Education using VR and AR Tools. In 14th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (pp. 306-313). Science and Technology Publications, Lda.

3. Kus, A., Kofoglu, M., Emreli, D., Arslan, R., Unver, E., & Kagioglou, M. (2019). “Development of Augmented Reality Application for Teaching Geometric Tolerances in Engineering Education”. Uludağ University Journal of the Faculty of Engineering, 25(1).

4. Huerta, O., Unver, E., Arslan, R., Kus, A., & Chotrov, D. (2019). “Application of VR and AR Tools for Technical Drawing Education”, Proceedings of CAD'19, June 24-26, 2019, Singapore.

5. Huerta ,O., Unver, E., Arslan, R., Kus, A., and Allen, J., “An Approach to Improve Technical Drawing using VR and AR Tools” Computer-Aided Design & Applications Journal, In press.

6. Emreli, D., Kofoglu, M.,Arslan, R.,Kuş,A., Unver, E. “Investigation of the Effect of Virtual Reality Teaching Material on Students Conceptual and Cognitive Learning Levels for Technical Drawing Education”, International Conference on Science, Mathematics, Entrepreneurship and Technology Education, FMGTEK19, April 12-14, 2019, İzmir, Türkiye

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