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STRUCTURED ABSTRACT

Creativity in Mechanical Design: The Use of Visually Diverse Ethnography Methodologies for Better Practice

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Beyond tolerance – educational practices that embrace diversity. (Teaching Strategy)

CONTEXT

The metrics of what a student may consider to be a "good" mechanical design have traditionally centred on a range of factors that make up the design being appreciated. For example, the use of the most appropriate material is determined by; the design's required strength, weight, cost and the environment that it must operate in. The shape and size of a good mechanical design is linked to factors such as; the direction and size of imposed loads and the expected design life. An example that encapsulates the included criteria may be found in a simple automotive connecting rod. The noted difficulty lies in the teaching method used to capture the required scientifically based criteria as successful design, and to then include elements of aesthetics (or visual appreciation) into the educational paradigm.

PURPOSE

The purpose of this paper is to initially explore and put forward methods for future research in the use of visually diverse ethnography techniques which may be applied to define additional criteria for the appreciation of what makes a "good" mechanical design. These methods would investigate the use of sensory appreciation rather than traditional analytical methods within the framework of a unit of study: Mechanical Design 1, is a unit of study that contains distinctly diverse cohorts of students, namely; aeronautical, biomedical, mechanical, mechatronics and space. This is an important aspect of the research goal, as it would help explore the level and potentially, the type of diversity between student cohort's efforts in arriving at a final design.

APPROACH

Visual ethnography research methods depend on the analysis of still and moving images in order to extract information that is not necessarily in the written or spoken form. The method is used in the analysis of what Rose (2016) defines as 'visual culture', or the way that visual media connects with life. Pink (2013) expands on the role of visual ethnography as being more than linked to human subjects by noting that it is, 'framed by disciplinary agendas and theory'. The key approach this paper takes involves;

1. Analysis of engineering design problems requiring graphical solutions e.g. a simple connecting rod.
2. Extraction of related visually diverse criteria.
3. Construction of a comparative evaluation table to represent the related criteria.
4. Formation of an initial framework to allow further analysis of results.
5. The use of statistical methods to compare features from noted successful and non-successful designs to establish numerical relationships.
6. The use of numerical relationships (as a tool) in the analysis of potential designs by students.

In the context of mechanical design, the information to be analysed could be in the form of appreciating; freehand sketches, orthogonal engineering drawings, Computer Aided Design (CAD) models, 3D rendered images and Finite Element Analysis (FEA) solutions in a tutorial or lecture environment. The framework of the study would then encompass the use of these visual solution presentation methods by a diverse student cohort appreciating distinct visual solutions to a given problem.

BACKGROUND

Visual ethnography is a qualitative research field that traditionally focused on the use of visual media such as photographic images, motion pictures and internet sourced graphics in order to convey a message. Berg (2012) defines its use (rather than by text) on being a means for 'explaining the social worlds and understandings of people'.

Berg (2012) goes further by emphasising that the effort should focus on the 'visual aspects of culture' rather than the images themselves. Likewise, Kress and Van Leeuwen (2006) discuss a 'grammar of visual design' that is linked to 'social interactions'. The use of the word 'grammar' is notable as it implies the existence of a set of rules for the analysis of images. This view is reinforced by authors such as Bang (2014) who openly discusses the use of graphic design as a way in which to convey particular emotions to the reader. Figure 1.0 illustrates some of the more human responses that may be conveyed to the reader using graphics that have a particular shape, size, orientation and shading with only black or white colours used.

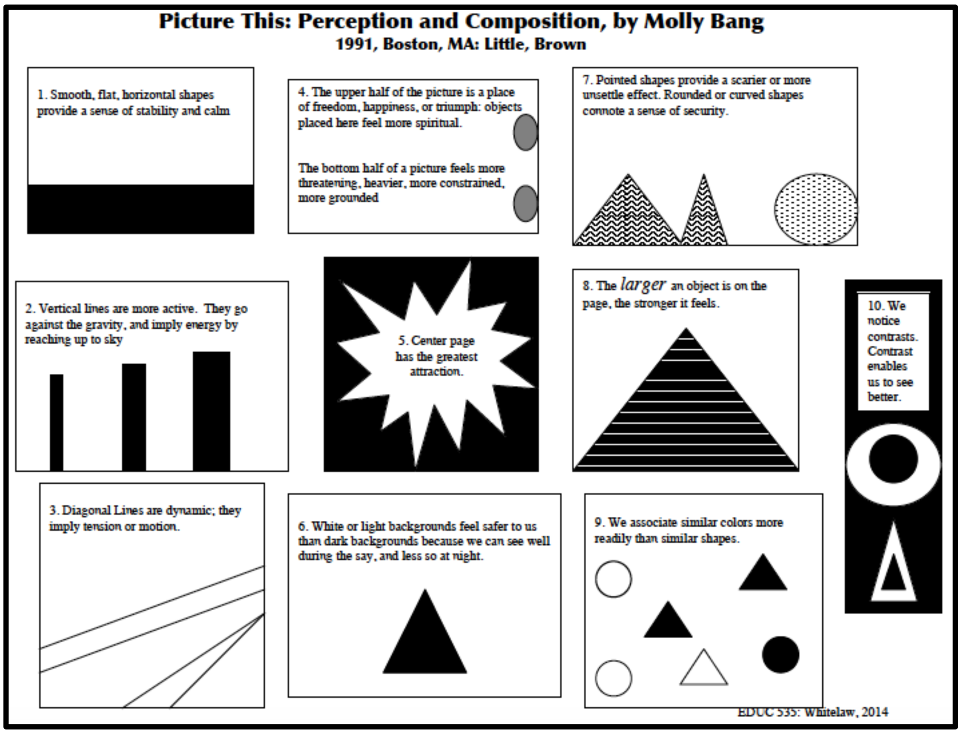

Figure 1.0 Picture This: Perception and Composition (Source: Bang 1991)

Silverman (2014) breaks down the types of visual data into two broad categories, 'Artefacts' and 'What people see'. The term 'artefacts' refers to traditional photographs as the medium for visual analysis. This has extended into what Marvasti cited in Silverman (2014) as the increased use of 'numerical analysis' (p. 356) e.g. spreadsheet, statistical representation in visual sociological analysis in lieu of photographs. Whereas, 'What people see' refers to the actual surroundings that the visual media has recorded e.g. video recordings. It is noticeably common for visual ethnography to draw on visual media that contains people within a social context.

But what gains are provided by using visual ethnography over conventional text-based methods? Pink (2013) notes that visual methods offer, 'continuity between fieldwork in research contexts that other media cannot'. It is this key benefit that will be explored in this paper. 21st century technology platforms readily provide the means whereby the visual representation of visual data is easily possible. However, Denzin and Lincoln (2013) highlight that there exists a 'slow shift to visualisation' for the evaluation of data and note that this trend is in a, 'stagnant state' from a tertiary education perspective as academia is still largely centred on conservative physical text-based media for information distribution.

CONTEXT

The importance and challenge of this study is to establish a suitable methodology that incorporates features of visual ethnography to enable the assessment of images that are generated by; student freehand sketches, engineering drawings and engineering analysis software. The diversity of a cohort found in the in the teaching space of the unit of study: Mechanical Design 1 is comprised of mechanical, mechatronic, biomedical, aeronautical and space undergraduate and postgraduate students. In terms of the design process, the area of interest is in the 'presentation' component highlighted in Figure 2.0 by Shigley et al. (2004). The transition from mechanical design solutions that required 'hand calculation' based approaches to engineering analysis to the current use of advanced non-linear FEA and immersive and human-centred computing design environments e.g. virtual reality solutions such as flight and driving simulators depicted in Figures 3.0 to 5.0.

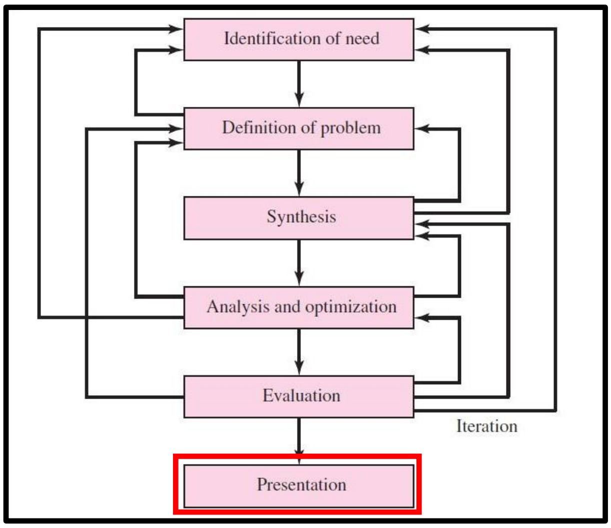

Figure 2.0 Phases in Design (Source: Shigley et. al. 2004)

Figure 3.0
LS-DYNA for Occupant Safety
(Source: LS-DYNA 2018)

Figure 4.0
Immersive Flight Simulation
(Source: Inside View 2018)

Figure 5.0
Driving Simulator
(Source: Drivewise: 2018)

Modern computer hardware used for engineering analysis problem solving has largely followed Moore's law in its ever increasing power, what is missing is a method that at least attempts comparative analysis of these solutions to a diverse audience.

METHODOLOGY

Conducting visual ethnography requires a framework to allow interpretation. In the context of images derived from photography, Pinney (cited in Cohen et al, 2011) states that images are 'compressed performances' and goes further to dissect the image into two sites labelled, 'production' and 'consumption'. Production is defined as the location that the image was taken and consumption, the location where the image is appreciated. The two sites differ geographically but more importantly the original intent defined in the production phase may change in the consumption across a period of time.

One method of qualitative image analysis is noted by Rose (cited in Cohen et al,2007 p.258-9) as using a question-based method of image analysis. A sample of generic questions that are not specific to Figure 6.0, 'an image of an art class taken early in the 20th century' (Rose cited in Cohen et al,2011 p.591-592) are included in Table 1.0.

Figure 6.0
'An early twentieth-century photograph of children in an art class'
Occupant Safety (Source: Beamish Museum Limited cited in Cohen et al, 2011 p.593)

Table 1.0 Simplified Qualitative Questions (Rose cited in Cohen et al, 2011 p.591-592)

Why was the image extracted?
Who are the originally intended audience?
What is the context of the image?
What does the image illustrate?
What are the main features of the image?
What is the medium of the image?
Is the image 'standalone' or part of a set of images?
What do different components of the image signify?
Are the diverse interpretations of the image aligned with those of the producer?
What different interpretations of the image may be made by diverse audiences?
What knowledge is included or excluded from the image?
How can the image be viewed?
How is the image categorised?
Is there a written commentary on the image ?
What is the relationship between the image and its diverse viewers?

The choice and number of questions presented forces the reviewer to selective focus an infinite number of lenses on as many facets as are required. Cohen et al, (2011 p.592-597) divide their findings of Figure 6.0 into three broad categories:

1. **The people in the image** (numbers, sex, age, clothing, behaviour, power relationship) with over 13 separate observations noted.
2. **The classroom and furniture in the image** (its age, number, condition, position, spacing, decorations) with over 20 separate observations noted.
3. **The photograph** (its condition) and the photographer (position, intentions?) with over 30 separate observations noted.

The examination of what appears to be a simple staged black and white photograph generates large volumes of data that requires analysis and interpretation of the image as it stands. Cohen et al. (2011 p.597) go on to suggest that, 'content and discourse analysis plus a modified version of grounded theory' are valid methods for image analysis. The opportunities created by image analysis are cited by Eisner (1997) as allowing us to, 'exploit individual aptitudes'.

Considering Eisner's point and Cohen's et. al findings, the use of a question-based method of image analysis (as noted in Table 1.0) is applied to a mechanical design component illustrated in Figure 7.0, which describes an image of a failed motorcycle piston and connecting rod.

Figure 7.0 Picture of a broken piston and connecting rod from a scooter. DR Racing Parts 65 cc piston, standard Suzuki Katana AY50 connecting rod (Morini two-stroke engine).

Table 2.0 provides a plausible set of responses to the general questions posed in Table 1.0 that is easily extendable and able to be tailored for a diverse audience.

Table 2.0 Simplified Qualitative Questions (Rose cited in Cohen et al, 2011 p.591-592), answered by Briozzo (2018)

Why was the image extracted?	To explain a failure of the connecting rod.
Who are the originally intended audience?	Mechanical design engineering students.
What is the context of the image?	The engine over sped and caused the connecting rod to fail.
What does the image illustrate?	The failed connecting rod and damaged piston.
What are the main features of the image?	The image shows the failed and still functional parts assembled.
What is the medium of the image?	Digital photography.
Is the image 'standalone' or part of a set of images?	Standalone.
What do different components of the image signify?	Each component carries out a unique mechanical function
Are the diverse interpretations of the image aligned with those of the producer?	The diverse cohorts and producer would need to be independently surveyed.
What different interpretations of the image may be made by diverse audiences?	Each diverse cohort would need to be surveyed with the results compared.
What knowledge is included or excluded from the image?	Details on the failed components is included. The additional components that surround the image are not included.
How can the image be viewed?	By way of a computer or mobile device.
How is the image categorised?	The image is of an existing device that has failed not a design in progress.
Is there a written commentary on the image ?	No.
What is the relationship between the image and its diverse viewers?	One needs to be established to suit the needs of each diverse group of viewers.

An alternate method of image analysis is applied to an image that has been generated by freehand sketching methods that uses a quantitative method to gauge the performance of key features of a mechanical design. This method allows statistical analysis to be more readily carried out. Figure 8.0 illustrates a simple but well drawn free hand sketch of a bearing system. Figure 9.0 defines criteria that the sketch needs to address and a comparative scale to measure the effectiveness of each of the criteria in relation to the sketch being assessed. The same qualitative method may also be applied to engineering drawings such as that described by Figure 10.0 and its accompanying criteria shown in Figure 11.0.

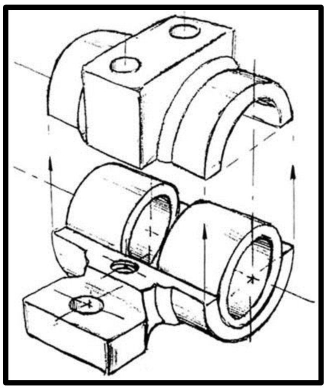

Figure 8.0
Pillow-block (Freehand Sketch)
(Source: MITOPENCOURSEWARE, Design Handbook: Engineering Drawing and Sketching, 2018)

GENERAL	0	2.5	5	7.5	10
SUITABLE DRAWING SIZE	-	-	-	-	-
LINE QUALITY	-	-	-	-	-
THREE FACES WITH ALL CYLINDER AND HOLES VISIBLE	-	-	-	-	-
REMOVAL OF ALL CONSTRUCTION LINES	-	-	-	-	-
PRINCIPALS OF PROJECTION					
PARALLEL LINES PARALLEL	-	-	-	-	-
ELLIPSE					
MAJOR AXIS ELLIPSE CORRECT DIRECTION	-	-	-	-	-
ELLIPSE PROPORTIONS CORRECT AND DRAWN	-	-	-	-	-
ELLIPSE CURVES BLENDED TIGETHER CORRECTLY	-	-	-	-	-
PROPORTIONS					
BLOCK	-	-	-	-	-
CYLINDER AND HOLE PROPORTIONS	-	-	-	-	-

Figure 9.0
Mechanical Design 1 Freehand Sketch Feedback Sheet
(Source: Briozzo, 2018)

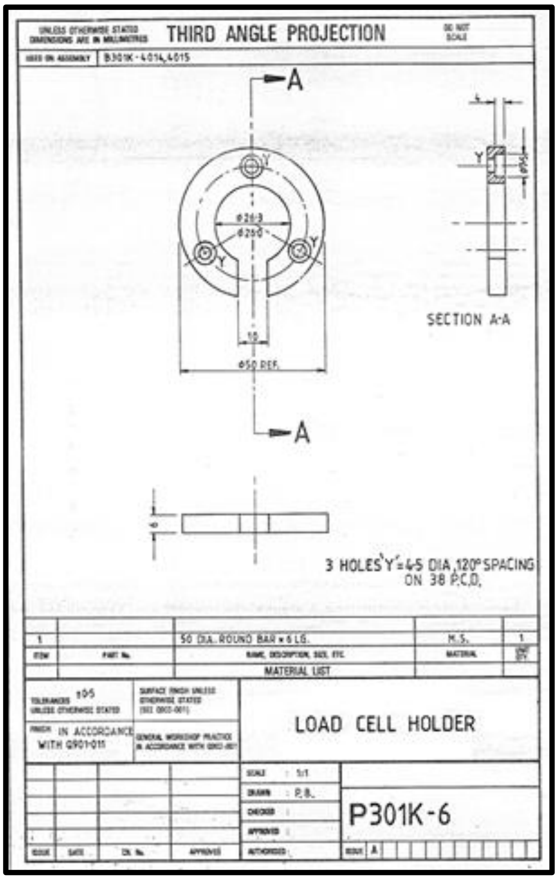

Figure 10.0
Load Cell Holder (Detail Drawing)
(Source: Briozzo, 2018)

Views:		
Enough orthogonal views and sections	0 1 2 3	
Views and sections correctly defined and labelled	0 1 2 3	
Hidden line detail	0 1 2 3	
Shapes fully and properly defined	0 1 2 3	/12
Line Work:		
Visible outlines 0.5 mm	0 1 2 3	
Sections 0.25 mm centre line, 0.5mm ends	0 1 2 3	
All other lines 0.25 mm	0 1 2 3	
Centre lines	0 1 2 3	
All surface textures/finish defined and realistic	0 1 2 3	/15
Dimensions:		
Not across part	0 1 2 3	
Linear, Diameters, Radii, Angles	0 1 2 3	
Arrowhead size	0 1 2 3	
Text height	0 1 2 3	
All features dimensioned (once only)	0 1 2 3	
All dimensions have reasonable realistic tolerances	0 1 2 3	/18
Drawing Properly Laid Out On Page:		
Suitable size	0 1 2 3	
Suitable scale	0 1 2 3	
Layout of views	0 1 2 3	
Layout of dimensions	0 1 2 3	
3rd Angle Projection correct	0 1 2 3	
3rd Angle Projection symbol (correctly located)	0 1 2 3	
Tolerance stack-up considered	0 1 2 3	/21
Interface to Corresponding Parts Correct:	0 1 2 3	/3
Title Block Details:		
Drawing title	0 1 2 3	
Drawing number correct	0 1 2 3	
Dimensional units defined	0 1 2 3	
Materials	0 1 2 3	
Treatments	0 1 2 3	
Drawn by initials (drafter)	0 1 2 3	
Sheet size	0 1 2 3	
Company name	0 1 2 3	/24
Definition:		
Item fully defined	0 1 2 3	
Drawing fully meets AS1100 requirements	0 1 2 3	
Is the drawing easy to read and understand?	0 1 2 3	
Could the pieces be made correctly from the drawing?	0 1 2 3	/12

Figure 11.0
Mechanical Design 1 Detail Drawing Feedback Sheet
(Source: Briozzo, 2018)

Rose (2016) proposes a visual methodology that incorporates four sites, 'the site of production, the site of the image, the site of the image's circulation and the site of the audiences'. Figure 12.0 illustrates Rose's methodology of the four modalities in graphical form. It allows for rearrangement of its circular sectors that fall under the dominance of their relevant sites and for the engagement of the relevant modality sectors that are relevant to the final presentation of a mechanical design solution generated by the design process described in Figure 2.0.

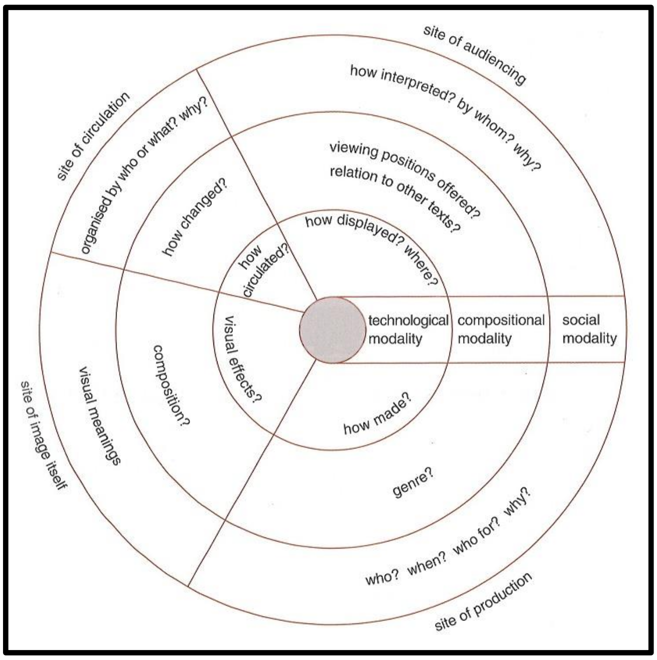

Figure 12.0 Sites & Modalities for Interpreting Visual Images (Source: Rose, 2016)

Students will use visual ethnography techniques to analyse a series of engineering design specific images and use a series of questions (similar to Table 2.0) to gain greater insights into mechanical design. The criteria (initially generated by the producer/researcher) is added to by the audience/students until saturation is reached in the modality spaces of; technological, compositional and social. Figure 9.0 addresses the skill set of sketching an engineering design concept, Figure 11.0 addresses the skill set of communicating engineering drawing against a set standard. An additional set of criteria to benchmark mechanical design analysis traits such as; loads imposed, boundary conditions, materials, shape and orientation is required to complement a visual ethnographic analysis and to fully appreciate a completed design.

THEORY

The analysis of images is open to a diverse range of methodology frameworks. However, in terms of which social research theory is most applicable to diverse image analysis, Cohen et al. (2011) note that grounded theory may be used. The reasons why are that the following key steps are broadly identifiable;

1. Gathering of visual material.
2. Coding of the visual material.
3. Generation of categories.
4. Qualitative discussion of the categories.
5. The formation of concepts.
6. The saturation of categories (and implied stop).

Konecki (2011) also notes that grounded theory (as applied to visual data), 'relies on visual data for constructing categories, describing properties and generating the hypotheses'. A diverse and comprehensive survey of a diverse group of students will be required to test the validity of the use of visual grounded theory.

RESULTS

The anticipated results are expected to be easily extractable from structured sources such as technical based images as these are highly, "dimension-driven" and the data that is required is easily extracted, tabulated and qualitatively assessed for diverse content. Surface or freehand based images pose a slightly higher challenge as they contain higher levels of subjectivity in their construct. However, the compiled data should yield a basic numerical relationship that is available for student use within the timeframe. Future educational application by the use of survey methods is planned to gauge student engagement with the concept and to gauge levels of types of diversity that may be encountered.

CONCLUSIONS

The expected conclusions relate to an acknowledgement that a relationship will be able to be made between the use of visually diverse ethnography methods and student generated mechanical design attempts that may be tailored to diverse cohorts. Initially, the use of the questionnaire as described in Table 2.0 is proposed to arrive at a paradigm that encapsulates a “good” mechanical design includes; size, shape, surface finish, operating environment and to some extent aesthetics, with one notable limitation being material properties which require physical testing, microscopy or chemical analysis methods that are outside the visual spectrum. Visual ethnographical analysis methods are well established in their context. Mechanical design analysis methods are also well established in their context. The connection between the two methods should yield positive measureable outcomes that will not only provide a new lens to gauge “good” mechanical design solutions, but a valuable educational tool to gauge all features of a mechanical design and improve the diverse student learning experience.

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KEYWORDS

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