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Original citation & hyperlink:
Mackie, E. (2011) 'Ergonomics Teaching within Industrial Design: an Evaluation of Understanding ' in Martin Anderson(Eds). Contemporary Ergonomics and Human Factors 2011: Proceedings of the international conference on Ergonomics & Human Factors 2011, Stoke Rochford, Lincolnshire, 12-14 April 2011. UK: CRC Press.
http://www.crcpress.com/product/isbn/9780415675734

ERGONOMICS TEACHING WITHIN INDUSTRIAL DESIGN; AN EVALUATION OF EVIDENCE OF UNDERSTANDING

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This paper describes the process employed by Coventry University teaching staff to facilitate 116 first year design students in an assignment relating to a transport device. Evidence of applied anthropometry was sought in a 'package drawing'. A questionnaire aimed to discover whether threshold concepts could be identified from previous ergonomics knowledge. Early indications show students are likely to declare that their knowledge has changed. Issues are discussed in light of how designers depict user mannequins and think about ergonomics given the contents of the coursework.

Introduction

One of the most fundamental components of ergonomics is anthropometry which according to Pheasant (2003) is 'the branch of the human sciences that deals with body measurements: particularly with measurements of body size, shape, strength and working capacity.' In order that Coventry University students learn to design for a range of differently sized people they need to be able to apply anthropometry appropriately within the design process.

This paper describes an investigation into the use of applied ergonomics information within a four week assignment entitled 'Create a vehicle or boat around yourself'. This project was prompted by the need for the students to see ergonomics as an integrated component within the design process. It would also provide the chance for the students to try new methods of representing user considerations within different vehicles. The title was also intentionally 'loose' in that students might interpret psychological aspects of their personality as well as their physical proportions within the exterior and interior design. This approach was recognised as being appropriate since potential vehicle buyers do not necessarily look primarily for anthropometric fit even when this is crucial to usability and comfort and

appearance can be more relevant to the user's lifestyle than the application of quantitative anthropometric data.

The project brief consisted of instructing the students to identify one type of transport device as the basis for their project, with the stipulation that is should not carry more than 100 people. This meant that the vehicle had the option of being either a car, motorcycle, city bus, light rail vehicle, tram, urban taxi, water taxi, boat or human powered vehicle.

It was stipulated that a range of concepts should be developed exploring the evolution of their identified transport device and a developed proposal for introduction 20 years into the future. The work submitted for assessment should be presented as a cohesive set of illustrations including package drawings, demonstrating the concept in its user context and setting.

The present study therefore aims to describe the strategies for collecting ergonomics data and describing how the students used this information in their understanding of their own characteristics and subsequent development of associated package drawings.

Research

The brief was prompted by a recognition of the way designers think and the relationship between user research led methodologies as illustrated in the 'pyramid of user led design methodologies' (Lindsay, 2003).

This pyramid shows that at the lowest level designers tend to design for themselves and imagine other users' experiences from their own perspective or assumptions. Moreover, a report investigating the use of anthropometrical data by Australian designers (Blewitt et al, 2009) found that designers would tend to take their own measurements and conduct verification trials to produce design solutions to accommodate population extremes involving the smallest and largest percentiles. Whilst it is important for design students to not design from their own assumptions (Myerson, 2007) it is also important to recognise that there has to be a procedural and transitional phase in learning knowledge and threshold concepts.

Threshold Concepts

Threshold concepts represent, or lead to, troublesome knowledge that is conceptually difficult, counter-intuitive or 'alien' (Perkins, 1999). Difficulty in grasping the threshold concept may result in the learner getting 'stuck' and holding an understanding that lacks authenticity and depth. In attaining the threshold concept, the learner moves from a common sense understanding, and from previously held, and apparent obvious beliefs, to a transformed view of the subject matter.

Meyer and Land (2003) define threshold concepts as concepts that: '...can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. They represent a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress.' It is argued that recognising and illustrating diversity within themselves may indeed be a threshold concept. In terms of anthropometry this was to appreciate that they were likely to be a combination of different percentiles in their proportions which would in turn affect their experiences of undertaking everyday tasks associated with different products and vehicles and environments.

Research

Student cohort

The population of Industrial Design students at Coventry University is fairly narrow. Most students are male and aged between eighteen and their mid-twenties, and so have limited life experience. The majority of students that enrolled on the module attended the half a day measuring session.

Introduction lecture

According to Durling et al (1996) the learning style of designers is more suited to teaching starting with the big picture before explaining details. The learning style would also accommodate a lightweight structure allowing for guided exploration as well as working with objective and logical data. Therefore before students were measured a lecture of about 1 hour was delivered with the aim to introduce anthropometry in terms of:

- Gaining a basic understanding of different ways that the human body can be described that is of use to designers.
- How percentiles describe dimensional information about the space constraints involved in designing for people.
- Understanding how to use percentile information in different design scenarios.
- Illustrating some examples of using anthropometry to solve some basic design problems.

'Static' anthropometry data collection has historically involved transport design students at Coventry being measured for twelve different dimensions using recognised measuring equipment. These dimensions were chosen to represent data appropriate to transport design such as those associated with informing the driving position such as sitting height and buttock to front and back of knee for example.

Organisation of the study

A sheet was provided in order for students to record these twelve measurements and space for inserting their percentile values along with that for UK male and female percentile extremes for comparison. On the reverse side it was suggested that

students personalise their data further by illustrating images of themselves as well as reflecting on the combination of their dimensions and their experiences with space and fit according to their interactions within a vehicle.

Anthropometric databases employed

PeopleSize 2000 (visual anthropometry software developed by Open Ergonomics Ltd which offers pictorial/diagrammatic representation of all measurements compiled using a variety of sources in order to accommodate a range of genders, nationalities and age groups) was used to convert all their dimensions into percentiles and to provide the students with the facility to find out the size of a particular body dimension of very small (2.5 or 5th percentile) and/or very large (95th or 97.5 percentile) females & males respectively.

Questionnaire design

The questionnaire was distributed a week after the introduction lecture and measuring exercise in mid November 2009. Responses were anonymous, completed by 47 students (with a few partial completions) and consisted of the following questions:

1. If you have studied ergonomics/human factors before please describe to what extent e.g. contents of teaching, exercises etc.
2. Please describe how you might consider anthropometry in your previous and current design work.
3. Please give an example of work where you think this knowledge will be crucial in design and how you might demonstrate this.
4. Has your knowledge and understanding of people's bodysizes changed since the measuring and PeopleSize exercise? Why do you think this is?
5. Do you have any suggestions regarding improvements?

Results of questionnaire

Regarding previous knowledge of ergonomics the majority of the responses showed that just less than half of the students had not studied ergonomics before. In terms of the students who had studied ergonomics before; it was discovered that just under a third declared they had studied ergonomics to either at GCSE and/or A level. Given that the majority of students had no previous knowledge of the subject all respondents stated that the lecture and handouts were useful. Comments ranged from:

> *"Yes, very I learned new things, not just about measuring people but also about my own body"*

> *"Yes I have never studies ergonomics in detail before and I believe it is crucial for a good design to have correct proportions and make the user comfortable"*

About an eighth of the students (6 in total) sited that it had taught them how to measure and slightly less (5 in total) that the introductory material was relevant to the course and industry practice.

Regarding how the students might consider anthropometry in their previous and current design work, responses were more focussed towards consideration of space and fit, designing to be user friendly and for different sizes of people in equal measures. Individual responses ranged from:

> *"Accommodating space for all sizes of people is something I will have to do in the future. It is essential"*

> *"Products will be useless unless they are the appropriate size and shape for the user to interact with. I will consider dimensions and allowances a lot more now"*

When asked to give an example of work where ergonomics knowledge was considered crucial and how they might demonstrate this; the majority of the students (approximately 40%) gave examples relating to either interior and/or interaction design. A number of respondents referred specifically to the brief to 'create a vehicle or boat around yourself' and stated:

> *"Looking at finalising the dimensions of my vehicle"*

> *"I can build around my dimensions first and then design for a larger group"*

With a number of students being more specific about the sizes and location of interior design elements:

> *"If I design an interior all the switches need to be within reach, the handles need to be the right sizes, etc. You can demonstrate this by drawing a person within the interior"*

> *"When specifying roof heights, seat spacing, handles, leg room. By using minimal people size in some cases and maximum in the other cases"*

The question intended to reveal whether a possible threshold concept had been identified; akin to expanding clichés about what it means to design for people, was the penultimate question posed. Approximately 45% of students stated that their knowledge and understanding of people's body sizes had changed since the measuring and PeopleSize exercise in terms of appreciating people's different dimensions. However, approximately 15% of students declared that their understanding had not changed. There was a tendency for those students who stated that their knowledge had not changed to slightly elaborate upon those aspects of their knowledge that had been revised stating:

"Not really although people on average are slightly bigger than I thought"

"Well not changed but given an in depth understanding to why some things like seats, handles are the way they are. This is due to the different sizes of people"

This is an interesting phenomenon as clearly some of their thinking has changed but not enough to be recognised as a threshold concept. Indeed it seems more like the students are aware that the boundaries of their understanding of the subject have altered but their underlying understanding of the subject matter has remained consistent. It could be argued therefore that these students might not be able to appreciate that their knowledge had changed unless they had cause to challenge it directly from undertaking the design brief that was set.

Atherton (2007) states that disciplines and subjects are very different and no one single curriculum design will suit all in terms of evidencing that a learner can become a practitioner. Since the delivery of ergonomics had become more integrated within the design process this prompted the last question. Approximately half of the students (24) did not suggest improvements. The rest of the responses suggested the lecture being shorter (6) and the measuring exercise time reduced (5).

Visual production of anthropometric data

The vast majority of students chose to represent their measurements in a visual rather than tabulated way. Many of the students showed photographs of themselves in postures corresponding to those illustrated in PeopleSize 2000. However the data on these photographs differed as some just showed dimensions alone whilst other showed dimensions and translated these in to percentiles. Moreover only a handful of students visually represented other mannequins' corresponding to male and female percentile extremes.

Package drawings introduction

A package drawing is a representation of a proposed design. According to Porter and Porter (2000) traditionally package drawings are a set of 2D orthogonal views usually containing three scaled depictions (side, front/rear and plan) drawn to scale in order to communicate the 3 dimensional space around the driver. The mannequins used in a package drawing are usually static and based on the 2.5^{th} female and 97.5^{th} male percentile sizes. Ergonomics data plays a critical part in establishing the occupant space and therefore the package drawing is a simple tool that can be used to show the range of users in a dimensionally accurate drawing that helps to capture the spatial relationships associated with activities conducted by the users within the engineered structure and location of a vehicle's mechanical components.

Examples of package drawings

There was a significant difference in the quality of the package drawings presented. The majority of students visually represented their own dimensions in a mannequin style depiction interacting with their vehicle from a seated driving position. However, not all students depicted all three views; with most showing just the side elevation combined with one other view.

Some of the best package drawing examples showed the operational paths of doors, bonnets and rear panels in terms of considering access and egress requirements, but there were more students that depicted these features on a separate views of the side elevation of the vehicle rather than as part of the package. In many cases the sight lines were a significant feature of the package drawings created. Storage needs were also depicted in terms of space within the vehicles rather than the types of luggage that might be accommodated. Levels of adjustability were not strongly featured as a result of most students choosing to depict their own mannequins rather than accommodating the largest and smallest UK male and female dimensions.

Conclusions

This paper presents evidence that the majority of design students used in this study can demonstrate some evidence of understanding ergonomics in a visual way to support their dimensions and percentiles. However this focus on personal depiction suggests this could be at the cost of a wider appreciation of extremes of percentiles despite the responses of students who participated in the questionnaire who stated that their appreciation of people's body sizes had changed since the measuring and PeopleSize exercises.

Interestingly some students questioned the accuracy of the anthropometric database source as they did not feel that they were particularly tall at approximately 6ft in height yet this dimension would translate into a $>90^{th}$ %le UK male value. This might account for the 5 students who stated their knowledge of ergonomics had changed due to converting their dimensions into percentiles.

Whilst package drawings were able to show that most students had designed their vehicles with some awareness of issues, without translation into three views the aspect of 'fit' is not so well proven since side elevations alone do not demonstrate whether a vehicles design is wide enough to accommodate extreme mannequins. Nor do these views show how the side of the vehicle is shaped from the roof into the body side.

Recommendations

The way in which design students were encouraged by the title of the brief to consider their own dimensions before other users with extreme percentiles however suggests that this might have be at the cost of designing their vehicles with a more inclusive focus. It is felt that this approach could be rectified by requiring that students visualise the extremes of population percentiles to sit alongside their own physical depictions. This has the potential to make them appreciate and reflect more upon their own proportions when evidencing their understanding of ergonomics in the context of accommodating wider population characteristics.

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