THE NEXT GENERATION OF INDUSTRIAL DESIGNERS CONFRONTS DESIGNING PROTECTIVE HEADGEAR: Using Advanced Human Factors Assessment Tools

Terri Laurenceau
Georgia Institute of Technology

ABSTRACT

The project of designing protective headgear became the focal point for a group of junior students in the fall semester of 2001 at Georgia Tech. The opportunity to engage the students in the study of human factors and anthropometrics as it applies to a specific design application was enhanced due to the use of advanced tools to assess human factors and ergonomic issues. The use of a 3D Full Body Scanner and exposure to DHM (Digital Human Modeling) software were introduced in the design process. Help from faculty and staff that have been trained in both traditional and non-traditional anthropometrics methods brought a more meaningful experience to the academic rigor of teaching human factors.

Re-designing protective headgear was not a new concept for a studio project. In fact, it was nearly abandoned by thoughts of a student revolt on the very first day of class. Deeper reflection revealed strength in the goals that such a project would bring. Synthesis of several critical assessments was evaluated for the project 1) the head is one of the most difficult and challenging forms to draw. It was determined that form development was a priority in the program and the introduction of a studio project that would require concentration on curvilinear shapes would be valuable 2) the nature of the project would prompt considerable attention to issues involving human factors, anthropometry and advancements made in the measurement and analysis of the data 3) a sufficient challenge in the materials and processes applications would provide intense hands-on activities.

Some concern regarding the introduction of new procedures to the studio project did exist. The scanning technology, DHM, anthropometry, and reverse engineering could give students a glimpse at usage of advanced technologies, at the same time exploration in traditional physical modeling methods, and manual anthropometry would provide a worthy challenge for students. Students learned simple anthropometrics measurement techniques and analysis of personalized 3D scan data. Experimentation with scanning inanimate objects provided the students an understanding of how reverse engineering is used in the design process.

The overall process of experiential learning through hands-on activities and the primary goal of how to implement a systematic methodology was a great challenge for the students. Many students felt a level of confidence for the first time, which in turn will provide the thrust for taking on bigger and more complex challenges in the future. The applications used for the studio project helped build skills and provided exposure to technology that will increase the students’ abilities to manage the process of innovation competently. This paper demonstrates how state of the art technology coupled with traditional tools and methods collate to create a dynamic learning experience for students. I will evaluate a number of
teaching methods used in this project that provided complexity and diversity while bringing about meaningful and innovative solutions, as well as a structure involving the use of advanced technology in design curricula. What could the next generation of industrial designers confront in designing protective headgear?

Terri Laurenceau
Terri Laurenceau is currently an Assistant Professor of Industrial Design in the College of Architecture, Department of Industrial Design, at Georgia Institute of Technology. Terri received her BID from Pratt Institute and MA from The Ohio State University. Terri has 22 years of diverse experiences as a professional industrial designer in corporate environments, consulting firms, and entrepreneurial ventures. Her research focus involves Traditional and Non-Traditional Modeling, Anthropometry and Human Factors, and the Use of Human Digital Modeling Tools to enhance design development and ergonomic evaluations in the design process.

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Project Planning
Thinking about this project created some reservation as to how the current group of juniors would approach this project. For the many merits that such a studio project maintained, some concern existed regarding the introduction of new procedures to the design process. It was determined that scanning technology, anthropometry, reverse engineering, and DHM would be introduced, discussed and/or used, giving students a glimpse at how and when advanced technologies might be useful in the design process. Exploration in traditional physical modeling methods also provided a noteworthy challenge. Hands-on workshops would be introduced intermittently to support teaching in critical areas such as model making, technical drawing, and anthropometry.

Georgia Tech is a research institution, so we have opportunities to collaborate with research groups and use advanced technologies throughout the colleges. Workshops sponsored by The Center for Accessibility and Environmental Access (CATEA) [2] under the Direction of Joe Koncelik provided hands-on training in anthropometry and full body scanning to faculty at Georgia Tech.

With the assistance of Barbara Christopher, a CATEA staff researcher, students were taught simple anthropometrics measurement techniques and analyses of personalized 3D full body scan data.
Each student created an accessory or attachment for the headgear using technology such as wireless communications. The technological assessments added another dimension to the project. This paper will focus primarily on the results of the headgear aspects of the project only.

**Phase 1 Research**

It was important for the students to gain an understanding of the diversity of protective headgears in the marketplace, so a list was compiled of possible categories of interest. Main categories included: Sports, Occupational, Emergency, Military, Medical, Therapeutic, Entertainment, and Recreational. The sub-categories list was much too long to include here, however some interesting new categories were uncovered such as the “Mosh Pit” helmet and the “Migraine Headache” helmet. Students provided a written document with a problem statement, design objectives, design criteria, market research, competitor analyses, patent research, and user definitions during Phase 1. Life Style boards were also created in Phase 1 of the project.

**Competitor Analysis and Market Research**

In the required textbook for the course, students learned that a successful product can be defined by its market differentiation and by its commercial value [3]. Students evaluated existing products to understand if new opportunities existed. Some students focused on specific companies they would use as possible inspiration to align a new product introduction. Others pinpointed problems with an existing product that would lead to a redesign.
User Definitions
Understanding the latent and tacit needs of the users of protective headgear required the students to follow research methods to gather the information needed. Students would do interviews with users, casual observation, surveys, or participatory research to define user’s characteristics, needs and desires.

The Focus on Human Factors
A general dialogue about human factors and anthropometry resulted in the students gathering existing human factor data related to head measurements. The students quickly realized that finding available anthropometric data of head measurement was not an easy task. Not only did the challenge exist in gathering the data but also the static diagrams seem to leave many confused as to how they would apply the information to their product designs. Head sizing would be a critical component to the success of the product, so the maximum gain to learn about fit mapping would require that the headgear would be custom designed to fit the head of the student. Partial success of fit mapping would be donning the finished model at the end of the final phase.

Measurement Activities
A wealth of information on anthropometry had been recently gathered as a result of Georgia Tech’s involvement in the CAESAR study conducted in the summer of 2000. The measurement techniques developed to conduct the CAESAR study would also help students to assess specific measurements they needed for the protective headgear project. Another very valuable resource was a study conducted by Dr. Bruce Bradtmiller of Anthrotech. His technical paper attained through the Society of Automotive Engineers (SAE) Technical Papers Series titled; Sizing Head Forms for Design and Development, provided insight to the determination of a proper fit for head forms.

In the study carried out by Dr. Bradtmiller, a three dimensional database of head and facial anthropometry for US children and youth ranging from 2 – 18 years of age was undertaken. The data collection involved state of the art measuring techniques the use of a 3D scanner to gain 3D shape information of heads and necks of volunteer subjects. The study was complimented with extensive traditional anthropometric measuring methods. The resulting information provided a series of sized three-dimensional children head forms.
to be used, as design standards for the safety helmet industry [4]. The head forms would be physically rendered using an automated milling machine [4].

This study provided the impetus for determining some of the procedures that were followed for the junior studio project:

- Traditional anthropometrics provided numbers allowing students to compare and evaluate their measurements in statistical format. They would determine what percentile of the population their head sizes would fall based on known anthropometrics data.
- The students were scanned in the 3D body scanner. This procedure provided each student with a 3-dimensional image of their bodies and shape definition of their heads, as well a list of body measurements and a digital file of their 3D image.
- Each student made a 3D mold of their own head in plaster as a back-up for the other two procedures.

For experimental purposes a study model of a BMX bike helmet was scanned to acquire digital data. The data was then exported to 3D Studio Max to evaluate with a 50th percentile male DHM manikin and a manikin created with similar anthropometry as the student. The files could be merged to visualize and determine fit and comfort.

It was valuable for students to learn the significance of both traditional and non-traditional measurement procedures. Students were excited to see and use the emerging technology. They were asked to make a comment regarding the scanning operation. Some student comments follow:
“This was an interesting and unique opportunity. The body scan gave me a good idea of my posture and how I look from a number of angles. I think this technology is interesting, easy to use, informative, and fun.”

“I thought the entire process was interesting. We definitely thought of some new alternative uses for this technology. It’ll be a fun challenge to incorporate this data & technology in future projects. I had a navel ring and it scanned just fine, however the scan stitched up my sides- weird.”

“It was really interesting to see how the body scanning was done. There was a little trouble with black fabric (for others), but my black shorts scanned just fine. This might be due to the fact that they were not shiny black material. It showed a little bit of shadowing around the neck but that might have been from the sports bra I was wearing. Overall it was really fun getting my body scanned.”

Phase 2 Conceptual Developments

Phase 2 was intensive involving conceptual development. At the start of Phase 2, having students write on an index card, became a way to address student concerns, frustrations, fears as well as triumphs. Students were asked anonymously to answer several questions:

1. What burning questions did they have that they wanted to ask?
2. What things about the lectures or discussions totally confused them?
3. What did they enjoy and learn during the week?

This became a good way to stay tuned to what was working and what was not for the students during the difficult parts of the project. Equipped with research uncovered from Phase 1, the students began the process of implementing their ideas and information into idea sketches, brainstorming activities, concept renderings, decision matrices, and form development study models. The following is a list of brainstorming techniques used during idea generation of Phase 2:

**Brainstorming**

Idea Rotation [3].
Scamper [5]
Idea Box [5]
Semantic 3 Minutes Sketching
Brainwriting [3].

**Idea Sketching**

Idea sketching was handled in both 2D and 3D approaches. Students were asked to develop at least 25 concept sketches and 10+ mini study models.
Concept Sketches
Student developed tight concept sketches of at least 9 concepts. A decision matrix was designed and used to evaluate the efficacy of a design against the design objectives and criteria.

![Fig. 1-9 Concept Sketches and Evaluation Model]

Study Model
A final full-scale study model was fabricated based on the results of the decision matrix. The study model was evaluated, revised and used to make the final model in some instances. For others a different material or a particular process of fabrication would be used to make the final design models.

![Fig. 1-10, 11, 12 Full Scale Study Models and Mini Sketch Models]

Modelmaking Workshop
Many students feared the approaching final phase of fabricating a final look-alike model. A 3-day workshop devoted to fabrication and modeling provided tips, demonstrations and hands-on activities with a variety of typical modeling materials. All materials and processes were viable options for the fabrication of the protective headgear models.

![Fig. 1-13, 13a Fiberglass Prototypes]
Final Models

*Fig. 1-14 Caving Headgear*  *Fig. 1-15 Hard Hat*  *Fig. 1-16 Bicycle Messenger Helmet*

*Fig. 1-17, 17a BMX Bike Racing Headgear with integrated Chin Guard*  *Fig. 1-18 Art Foundry Welders Headgear*

**Phase 3 Finalization**

This Phase of the project involved the completion and documentation of the entire project. The students completed technical drawings and assessments, as well as a final look-a-like model, product environmental renderings, and the process book. Manufacturing specifications were discussed in real world scenarios allowing each student to see specific problems or limitations in their designs. This would cause many to go back to the drawing board or computer to refine solutions.

**In Conclusion**

This project was one that helped in establishing a paradigm of teaching for the inclusion of traditional and non-traditional tools where a creative and meaningful learning experience for undergraduate industrial design students was sought. The overall goals for this project where achieved based on the following points:

- It provided insight as to where, when and how to implement emerging technology such as 3D full body scanning in the product design process
- It opened the doors to other possible uses of the technology for research and teaching
- It provided diverse learning activities where students became engaged in an experience that enhanced their understanding of anthropometrics and human factors.
- It provided evaluative information about the operation of the 3D body scanner and a collection of 3D anthropometrics data for the students.
- Specific teaching pedagogy was applied and documented during the project, which could prove helpful for others faculty.
- Experiential learning techniques helped to increase student confidence levels.

Every project takes a specific set of requirements and goals. This paper documents a specific type of project for the design of protective headgear. I believe it is of value to document design curricula particularly when new technology may involve some degree of change in the teaching pedagogy. As technology advances bringing ways to enhance the process of innovation, the introduction of new tools and their uses is critical in the academic setting. Providing exposure to students as to the uses of future technology will benefit academia, research and industries return on investment.
References


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Digital Human Manikins (Fig. 1-6)
Scanned Image of Chris Edward Head (Fig. 1-7)
Angela Raxter at the computer (Fig. 1-8)
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Final Model Susanna Johnston of Construction Hard Hat (Fig. 1-15)
Final Model John Jower of Bicycle Messenger Helmet (Fig. 1-16)
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Final Model of Hayoung Coffmans, Art Foundry Welders Headgear (Fig. 1-18)