Compression Learning for Product Design Education - Research and new methods in Design Education

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ABSTRACT:

The amount of new skills, understanding of globalization and increased project scope that has been added to the professional practice of product design is now putting stress on product design education departments around the world. As a result of demand from industry, design thinking, sustainable design, service design, user experience design, design research among other areas of specialization are now entering product design curriculums worldwide. To address this issue this paper will introduce the solution of Compression Learning to address this increase in learning content. Theoretical support of compression learning will come from a broad number of sources in the fields of: design education, computer science, psychology and general learning theory. Practical application of compression learning will be in the form of two case studies that included over 424 product, visual and interior design students at various curriculum levels over the past 5 years. The findings of this educational research have laid the foundation for a method of teaching product design that addresses the issue of increased subject matter mastery at the expense of traditional core curriculum. The results of this research revealed that students are capable of combining and learning a variety design skills and methods simultaneously earlier in the curriculum to better understand, apply and include new and more complex product design workflow and methodology later in their design programs. This research offers examples to professors, lecturers, instructors and academic administrators of product design education programs who wish to add value when planning pedagogical improvements to their class teaching.

Keywords: Design Education, Product Design, Industrial Design, Compression Learning

1.0 INTRODUCTION

Students today have new needs and learn differently than they did 10 years ago (Palfrey, Gasser 2008). Additionally, there are a variety of new subjects that have evolved that design students now must know, understand and include in their skill sets in order to be employable in the future. As a result, professors, lecturers and instructors of product design have had to debate the priorities of the curriculums they are teaching within (Shreeve 2011). One of the negative externalities of the inclusion of new subjects is that it can potentially weaken the core subject matter mastery that comes with more traditional design degree program (2009 Thompson). Drawing, computer aided design, materials and manufacturing processes, design studio, design theory, model making etc. are now seeing competition from new additional curriculum content. Just as computer aided design was added to design curriculums in the 1980s and 1990s, so is the inclusion of design-thinking, co-design, social media, design research, innovation and systems design are now being considered.

Product design and design education have been looked at very critically over the past 12 years (Koh 2012, Sharma, Kiloskar Tovey 2011, Cuisiner, Tornare 2011, Shedroff 2001). In light of the current economic slowdown that affects the entire globe, design education has had to take a long hard look at what it is they are offering to students, and what it is they are offering to industry when those students graduate and enter the now, very weak global job market. New content and subject matter has grown out the need for product designers to be more culturally aware of the world and the people for whom they will be designing for as they consider solving larger problems using design (Valtonen 2009). In order to accomplish this task of addressing a wider scope of problem identification, design students are beginning to move from solo self-expression to teamwork with emphasis on business knowledge, ethnography, technology and environmental science (Petersen, Curedale 2012).

Product design as a discipline has seen many periods of refocusing due to prevailing economic circumstances. It has gone from a crafts and industrial based focus to user centered (Bruseberg and McDonagh-Philp 2000) and an experience focus (Shedroff 2001) to a design outcomes based focus (Love 2009) in just the last 15 years. Increasingly, the approach of product design tends to be towards finding solutions to large and complex issues and understanding the relevancy of design to the larger whole (Valtonen 2009). Using design to develop economic policy, solve complex social problems and even to attract foreign investment at the government level are all now making their way forward in the effort to right the global economy. Students who are studying design need to be aware of these implications to the scope of design, and how their degree in design can offer them a wider choice of trajectories upon graduation (Lloyd 2011).

In order to address these changes to product design education, this paper will reference how machine learning theory leverages learning in the compressed data domain in order to make learning and decoding more efficient (Calderbank, Jafarpour, Schapire 2009). Increasing the quantity of the content and the understanding of how it can be applied in a student's later career requires an understanding of learning theory and how procedures and concepts interact (Rittle-Johnson & Siegler, 1998). These concepts and procedures from learning theory will support compression learning.

Two case history examples illustrate the use of compression learning in an empirical learning environment. In this research, students were exposed to compression learning methods at a 4 year publically funded national university of science and technology as well as a 3 year private design college. Both schools are located in Seoul, South Korea.

2.0 CHANGES IN STUDENTS NEEDS/CAPACITIES TO LEARN

Today's "digital natives" studying design or any other highly epistemological subject grew up with the computer and the internet. Many do not know what a world without internet was like before 1980 when the first social digital technologies came online like Usenet and bulletin board systems (Palfrey, Gasser 2008). Increasingly, online education is making its way into the mainstream. Online learning programs like Coursera.org are offering classes that have student numbers in the +10,000 class size. Students are becoming familiar with online learning and are increasingly savvy with acquiring class credit through programs that are organized to offer certificates and university credits. With the introduction of the Smartphone in 1997 by Ericsson, and the broader US rollout by Kyocera in 2001 (Wikipedia 2012) , the intensity of internet exposure in daily life has now gone mobile which means that for many students, they are connected and interfacing with the internet most of their waking hours. This presents new challenges to educators both in and out of the classroom.

In developmental psychology, articulating how procedures and concepts interact is critical to an understanding of how development occurs (Rittle-Johnson & Siegler, 1998). Broader understanding of how these new technologies impact learning and motivation will reveal ways in which to lever them by educators. For example, many product design programs still today introduce 3D CAD procedures and concepts into the curriculum in the 2nd or even the 3rd year of study. After working with and polling South Korean, Chinese, Mongolian, Filipino, Slovakian, Finnish and Japanese students ranging in ages between 19 and 23 during the course of this paper's research, it was found that the learning of highly complex and intensive CAD and 3D printing concepts created a bottleneck to the development and absorption other critical areas of the design curriculum. Because the learning of 3D CAD is now a combined computer and internet based activity, it is perceived by students as more important than other traditional industrial design skill-sets and theory, thus should be among the first subjects taught in order to compel and motivate the student to learn faster and further beyond this initial skill set.

Because of the rise of mobile and cloud computing, social networks and smart-phone technologies, students are able to increase their interactions outside of the classroom. The sharing of data and research at the beginning of projects becomes more viral, and less time is used in class updating team members. This leveraging of smart phone, internet and CAD technology in the research phase of a project has allowed the concept of compression learning to broaden its scope and add new subject matter mastery to product design curriculums.

3.0 PRODUCT DESIGN CURRICULUM SHORTCOMINGS

This issue of increased subject matter into the design curriculum has lead to a tendency to replace less rigorous design course material with more rigorous subject matter from other design-related areas (2009 Thompson). As product design departments increase their content offerings and rearrange their curriculums to meet the needs of the design graduate market, these issues have risen out of the desire to offer more rigor without diluting what makes a particular traditional program valuable. This is partially due to the prioritization between hands on skill building and tool learning, with that of broader design process, strategy and team skills like: problem identification, problems solving and complex systems design which are being explored by the disciplines from within the fields of design research. This new focus of design education includes many methods of teamwork, design-thinking, brainstorming and the inclusions of new disciplines from ethnography, anthropology, psychology, sociology, economics, cybernetics etc. in its workflow to solve a raft of new problems that did not exist before. This thrust of new content has effectively threatened the importance of core curriculum courses that have traditionally served as the foundation of product design education.

In a paper submitted in 2009 regarding the empirical strain of design thinking, Love posits that changes are needed, towards more sophisticated understanding of complex systems design and prediction of the behaviors of design outcomes in complex design solution spaces (Love 2009). These outcomes in design solution spaces Love mentions, are where compression learning direct their benefits to the student learner of product design and it's often multiple and complex methodologies, tools and processes. If students can learn more quickly and comprehensively: computer, cad software, craft and drawing skills, they then can focus more so on the outcomes of their design concepts and how they affect the user through more rigorous design testing and the inclusion of other research into their designs.

4.0 COMPRESSION LEARNING DEFINED

Compression learning can be, although not entirely, defined by the combining of no less than 5 traditional core curriculum product design courses into a single course. It can be a combination of any choosing by the instructor (i.e. design research + design thinking + 3D CAD + 3D printing + design presentation etc.)

The need for the acceleration of skill and design tool mastery of traditional design learning content when fused with design research methods needs earlier introduction into design education curriculum. As noted by (Strausse, Arnold, 2009) the future of design research lies in creating new methodologies to solicit unbiased responses from people for the purposes of understanding their perceptions, perspective and behaviors. Research methodologies focused on providing insight into the ideation phase of design show the most potential for growth in the coming years. The time it takes to learn and master concept ideation phase product design skills must be reduced in order to make room for the learning and application of these new research methodologies. Compression learning can be used to accelerate learning, especially in the first 2 years of design school curriculum where traditional courses are taught as individual stand alone courses. Due to internet communication, CAD and social media technologies this need not be the case anymore.

Prerequisites are no longer necessary to build a foundation when using compression learning. Combining design skill building and tool mastery earlier on in the curriculum allows room for more advanced learning subjects later in the curriculum. In order to understand a workflow that professional designers use on a day to day basis, compression learning provides combined design process and tool learning at the beginning of design education, rather than later after a certain level of core skills/prerequisites are acquired.

Compression learning does however, put a new demand on those choosing to utilize its method in their teaching pedagogy. Careful syllabus planning is necessary to allow enough time to introduce, practice and connect the skills and tools being taught. Learning tools, skills and design process methodology together helps make better sense of the "why" and the "how" tools are used to design with. Some of the challenges that were faced by students during the research of compressed learning were confusion, frustration and stress. With careful one on one student/teacher interactions during class time, small group learning and using social media technologies outside of class, these issues were resolved.

5.0 PREMISES OF COMPRESSION LEARNING

Teaching and curriculum innovations both contribute to improve learning. The literature on teaching and instruction that leads to higher levels of learning is comprehensive and conclusive (Creemers 1994, Brophy and Good 1986, Joyce and Weil 1996, Joyce et al 1997). Learning how to learn, increased capacities to learn and work smarter, fully integrated successful teaching strategies across the entire staff ensure maximum impact on learning and the adoption of the many learning models that are well developed all lead to higher levels of student learning than normal. Teaching is more than just presenting material, it is about infusing curriculum content with appropriate instructional strategies that are selected in order to achieve the learning goals the teacher has for his or her students. Successful teachers are not simply charismatic, persuasive and expert presenters; rather, they create powerful cognitive and social tasks to their students, and teach the students how to make productive use of them. The purpose of instructional leadership is to facilitate and support this approach to teaching and learning (Hopkins 1997).

Compression learning is derived from the ontologies of three areas of academic research: 1) Machine learning/data compression, 2) Boolean algebra and 3) Procedural learning theory. These subjects exist in the disciplines of computer science/artificial intelligence, constructive solid geometry (cgs) and psychology.

In the area of computer science and AI, machine learning in the compressed domain is possible. It has been proven that signal data can be utilized or learned from in its compressed form. (Calderbank, Jafarpour, Schapire 2009). The first of these premises for compression learning is borrowed from machine learning. Machine learning in the compressed domain does not waste resources and sacrifice storage capacity because it can only use raw uncompressed data. Compression learning in design education also applies this learning concept that exists in the compressed data domain of AI. The analogy that is created between compression learning and machine learning, allows the product design educator to combine the most critical learning concepts in each individualized course), and boost their relevancy and comprehension for the student without losing any of their relevant qualities. Case study one leverages the concepts of machine learning to combine traditional design skill learning with some of the new subjects design education is adding to curriculums (i.e. social media, co-design, systems design, teams design etc.).

The second of these theories supporting compression learning is applied from Boolean algebra in relation to constructive solid geometry (CGS). By taking a number of individual subjects (i.e. primitives) and combining them cleverly using Boolean union and intersection connectors, only the essential elements that are necessary in a design process workflow remain. See figure 1 next page.

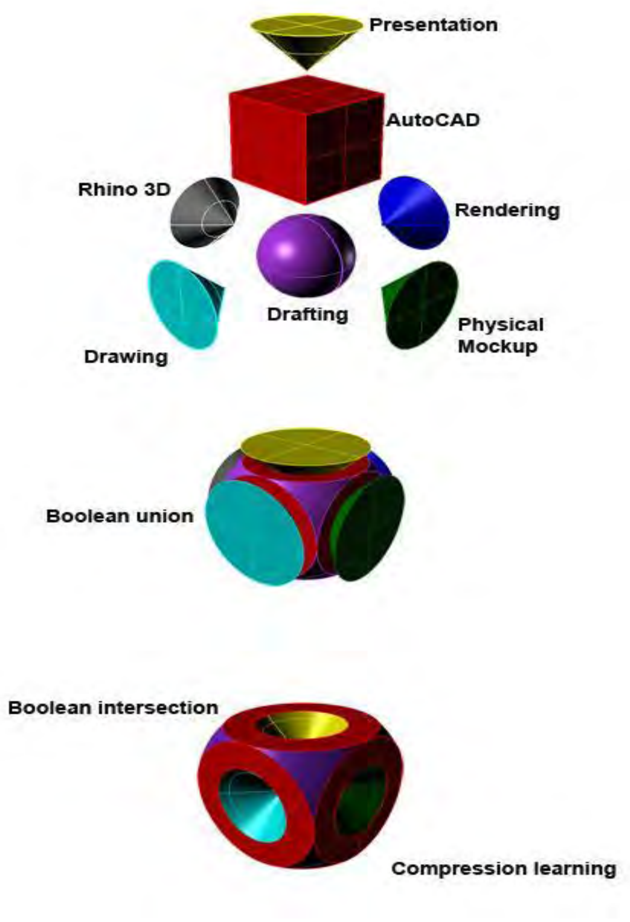

Figure 1: Boolean solid geometry metaphor chart

The third area of research that is applied to compression learning comes from the study of procedural memory. Procedural memory is created in the brain through the repeating of an activity over and over again to align the neural networks so that the activity is produced automatically in the future. Skill learning and repetition priming are aspects of a single underlying mechanism that has the characteristics of procedural memory (Gupta Cohn 2002). Boolean theory, skill learning and repetition are applied extensively in case study two of the research collected for this paper.

Getting beyond surface style learning of rote education and into deeper forms of memory, leads to depth of knowledge and critical thinking abilities. The dimensions of depth of knowledge are surface (superficial) versus deep, with the implication that surface is poor and deep is good (cf. Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Ericsson & Charness, 1994). Deep-level knowledge is associated with comprehension and abstraction and with critical judgment and evaluation (de Jong & Ferguson-Hessler, 1996). Deep-level knowledge has been structured and stored in memory in a way that makes it maximally useful for the performance of tasks, while surface-level knowledge is associated with rote learning, reproduction, and trial and error (Glaser, 1991). Teleological semantics is the meaning possessed by one who knows not only the surface structure of a procedure but also the details of its design (Star 2000). In case study two of this paper's research, a pre selected design concept is introduced to the class so the students are able to focus solely on learning the methods of developing the concept without letting the added stress of creativity enter the equation. Using what Star states in his paper, the educator progresses the development of the design concept using a total of 4 different design methods in a typical design process. This repetition using the same concept in each method deeply embeds the designs details into the memory of the student so that the next development method becomes easier to learn and apply in the next step of the process.

A procedure can be cognitively represented on multiple levels. On a very superficial level, a procedure may be represented simply as a chronological list of actions or steps; on a more abstract level, a procedure can include planning knowledge in its representation. Planning knowledge includes not only the surface structure (the sequential series of steps) but also the reasoning that was used to transform the goals and constraints that define the intent of the procedure into its actual surface structure (VanLehn and Brown 1980). It is this planning knowledge and ability to reason out the steps in the design process that compression learning aims to develop. In order for students to better imagine how they are to express their creative ideas using modern tools and techniques in design, it is better to introduce these tools and methods early in the curriculum so that confidence and neural pathways can be created.

6.0 CASE STUDY 1: CONCEPT DESIGN 1 AND 2

Case study one is from a public university that offers a four year undergraduate product design program that focuses on industry cooperation and professional development of product design graduates. It is the oldest product design undergraduate program in the nation of South Korea, beginning its offer of industrial design degrees in the 1960s.

The seminar style classes taught during the research gathering phase of this paper were Concept Design 1 and Concept Design 2. A total of 271 students were included in this case study enrolled in class sizes ranging from 14 to 28 students per class between years 2008 thru 2012 on a biannual (spring/fall) 3.5 month per semester schedule. Concept design 1 focuses on identifying a problem in contemporary Korean society and solving it through design research and concept development workflows. Concept Design 2 builds on the learning in concept design 1, but goes outside of the Korean market to understand a foreign market, its users and problems.

6.1 CONCEPT DESIGN 1 and 2 (3rd year students)

This case study of compression learning focused on the combined application of 11 distinct design skill-sets and tools to identify a unique problem and use a variety of methods to generate a conceptual solution (see figures 2-4):

1) Team building
2) Project communication among team members
3) Data collection/problem identification
4) Design synthesis/problem solutions
5) Presentation skill building
6) Sketching skills
7) 2D and 3D CAD skill
8) Art Direction skills
9) Storytelling skills
10) Team vs. individual skill building
11) Final concept presentation skills

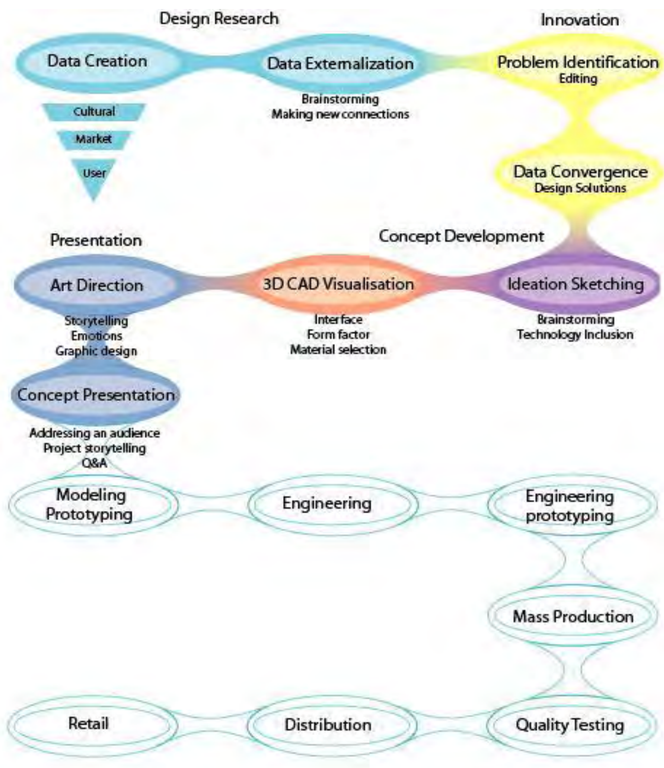

Figure 2: Concept Design 1 Chart

Figure 3: Student Work (Korean market)

Figure 4: Student Work (foreign market)

6.1.2 RESULTS

Many students voiced their confusion with the order of methods and why they were being exposed to the many skill sets and tools together. Most students enrolled in the class have not had the experience of designing for a client or an audience of other disciplines for that matter. It was only after the final presentation where all of the design teams projects were on display in front of an audience did they understand the value of what they were learning for the past 16 weeks. Here in lies the value of compression learning. Understanding how designers connect the skill sets, methods and tools of industrial design to produce a variety of design solutions for a client presentation is at the heart of compression learning.

7.0 CASE STUDY 2 - FOUNDATION DESIGN SYSTEMS (FDS)

Case study two is from a private college that offers a 3 year associates degree program that gives graduates a foundation in the unique product design skills that will allow them to be effective entry level designers in the Korean SME economy, or generate enough of a portfolio to apply to a 4 year program where they can acquire a more advanced degree skill sets, knowledge and theory.

Foundation Design Systems is a course that introduces a number of design tools and methods to first year level design students. Over the course of the four years of research into compression learning, 96 students were taught in this lecture/lab style class setting. The course is structured to introduce several areas of product design tools and methods. Traditional drafting, AutoCAD 2D, Rhino 3D and physical mock-up fabrication based on a 3D Rhino model data. Application of teleological semantics and Boolean theory is applied and incorporated in to the class pedagogy in order to promote deep level knowledge of methods and tools as opposed to mere superficial learning.

On the first day of class students are introduced via lecture, the entire design development road map (research thru retail distribution) that is typically used in industry to provide context for the semester. This case study of compression learning focused on the combined application of 7 distinct design skill-sets and tools to understand how they relate and interact with one another during a typical design process scenario:

7.1 FOUNDATION DESIGN SYSTEMS (1st year students)

This case study of compression learning focused on the combined application of 7 distinct design skill-sets and tools to identify a unique problem and use a variety of methods to generate a conceptual solution (see figures 5-13):

1) Traditional 2D drafting techniques (4 weeks)
2) 2D AutoCAD drafting techniques (4 weeks)
3) 3D CAD Rhino modeling (4 weeks)
4) CAD model visualization(1 week)
5) 3D CAD drafting and drawing output (1 week)
6) Physical modeling based on 3D data base (1 week)
7) Final project presentation skills (final week)

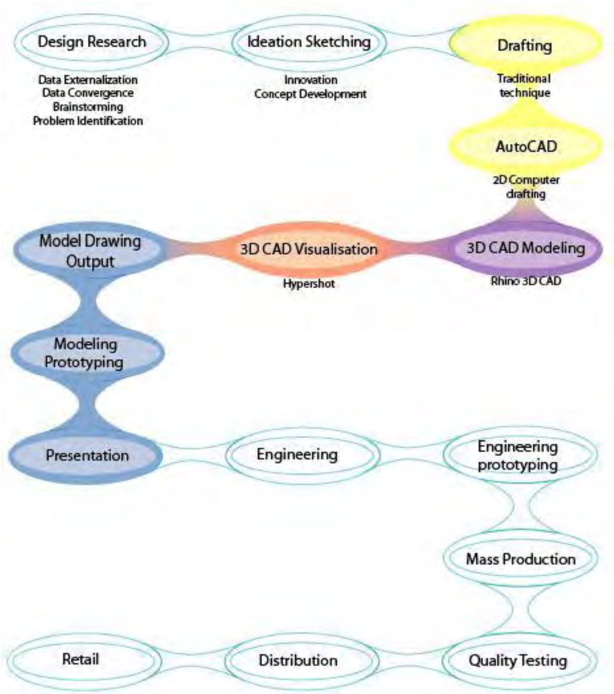

Figure 5: Foundation Design Systems Chart

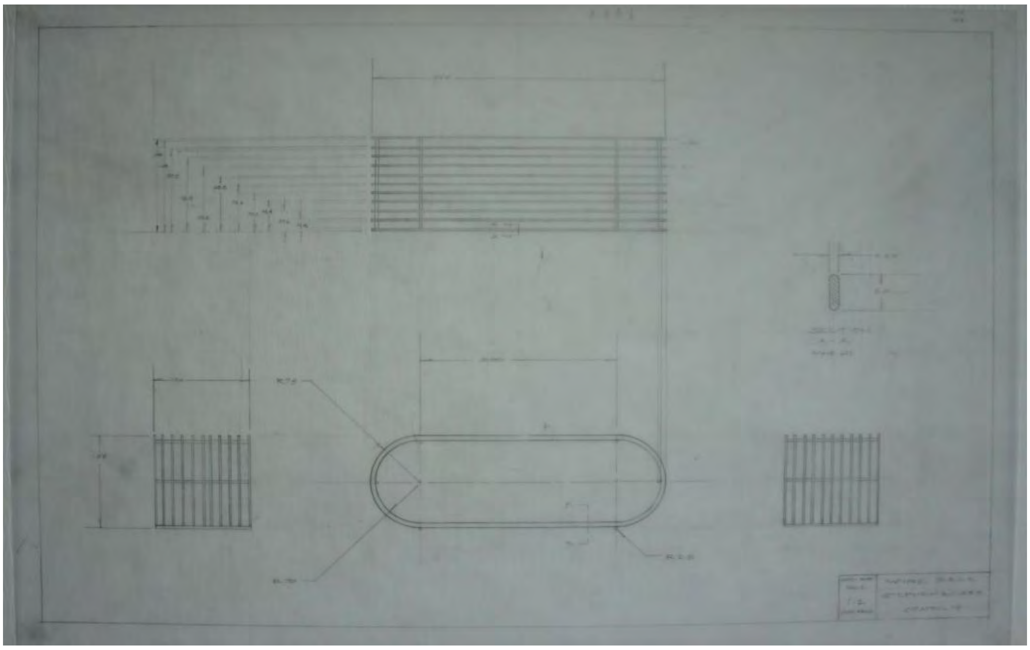

Figure 6: Traditional Drafting on vellum.

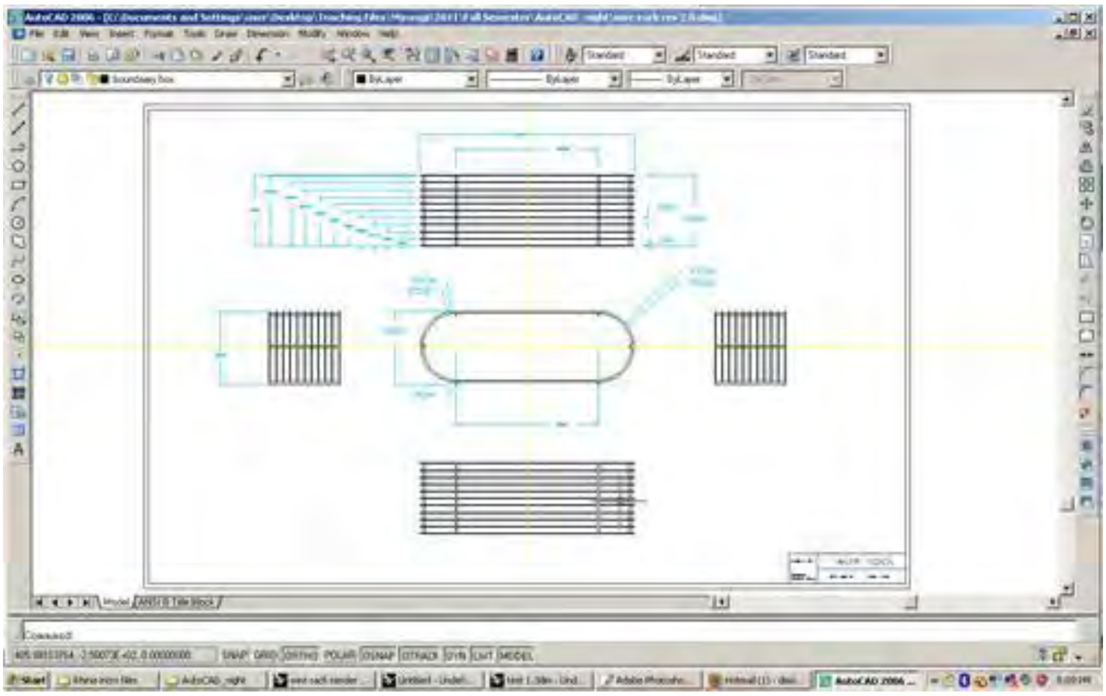
Figure 7: AutoCAD 2D screen shot.

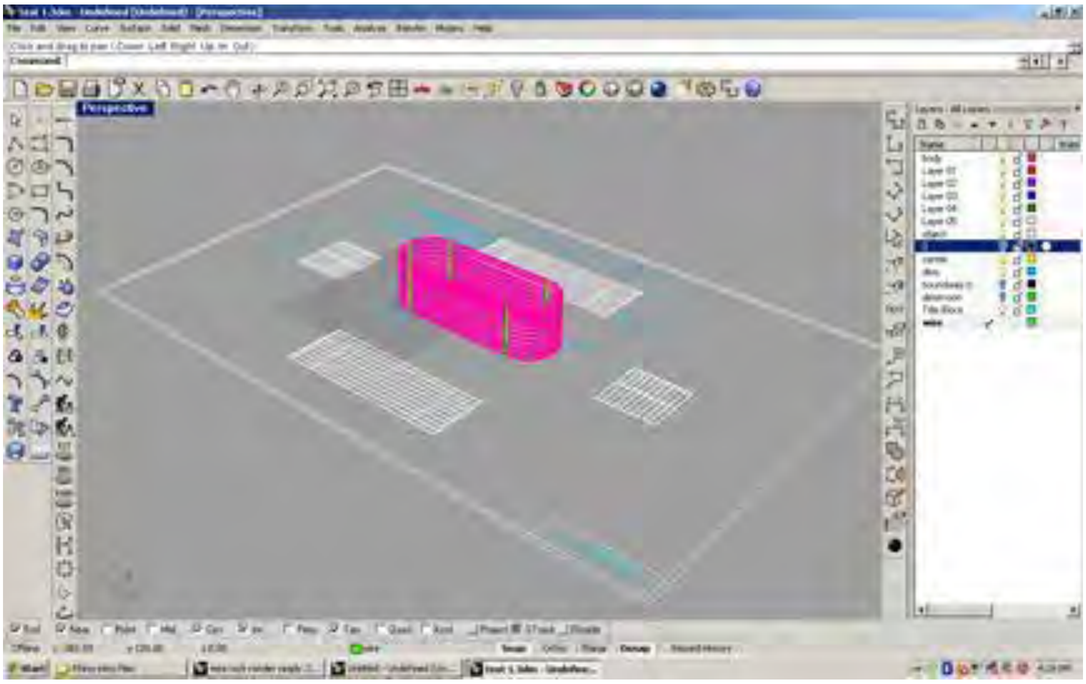
Figure 8: AutoCAD import to Rhino 3D CAD screen shot.

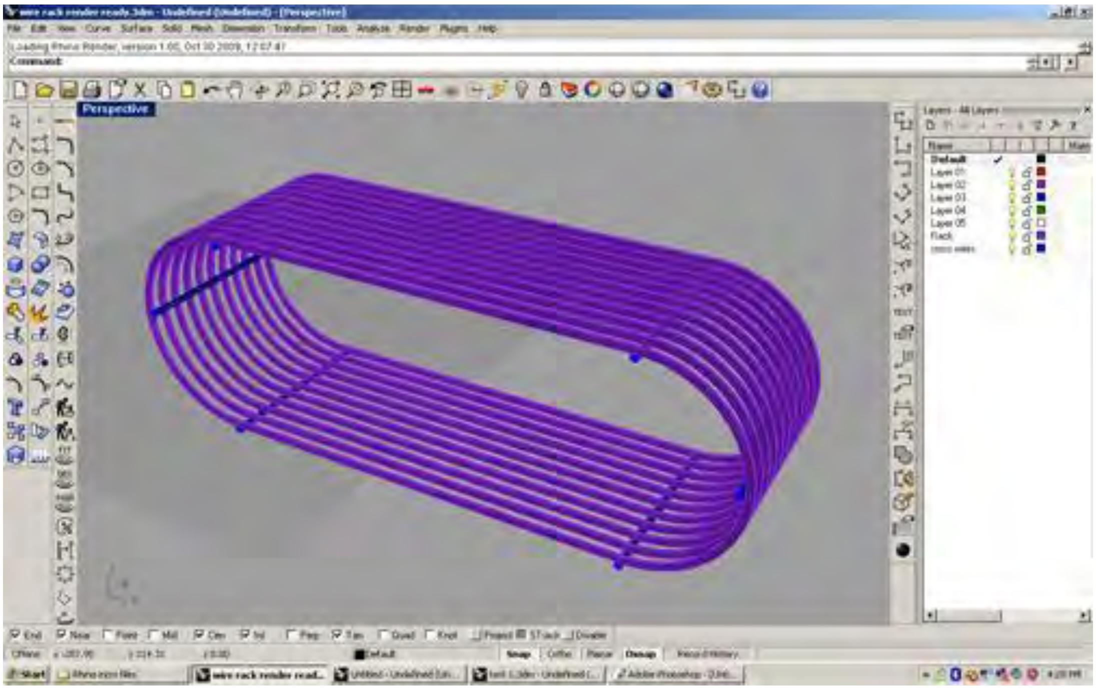

Figure 9: Rhino 3D model screen shot.

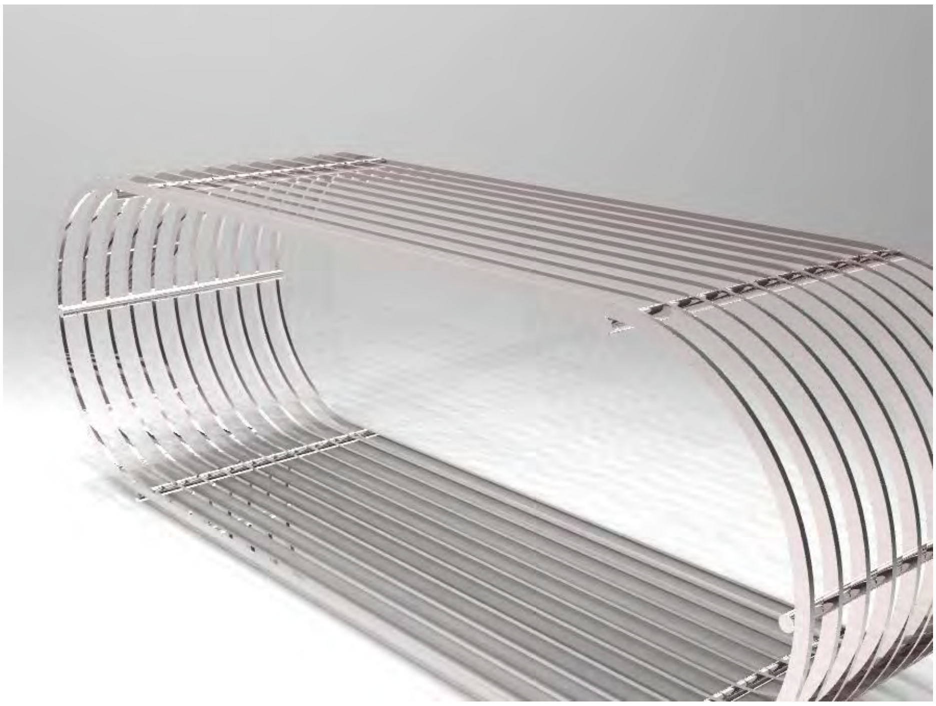

Figure 10: CAD model visualization screen shot.

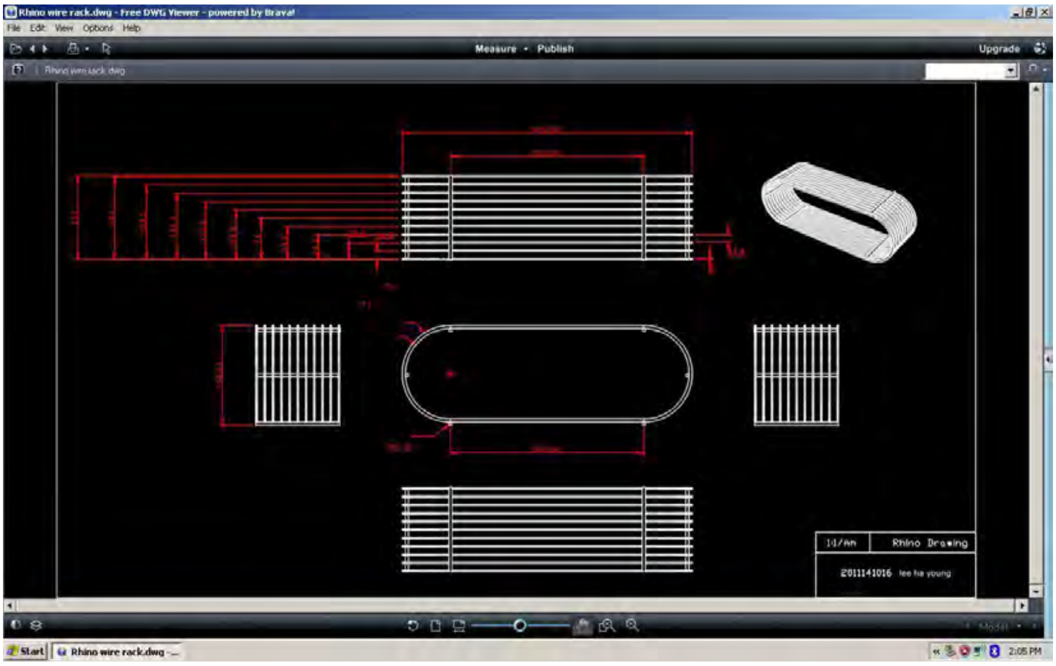

Figure 11: Rhino drawing output screen shot.

Figure 12: Laser cutting workstation.

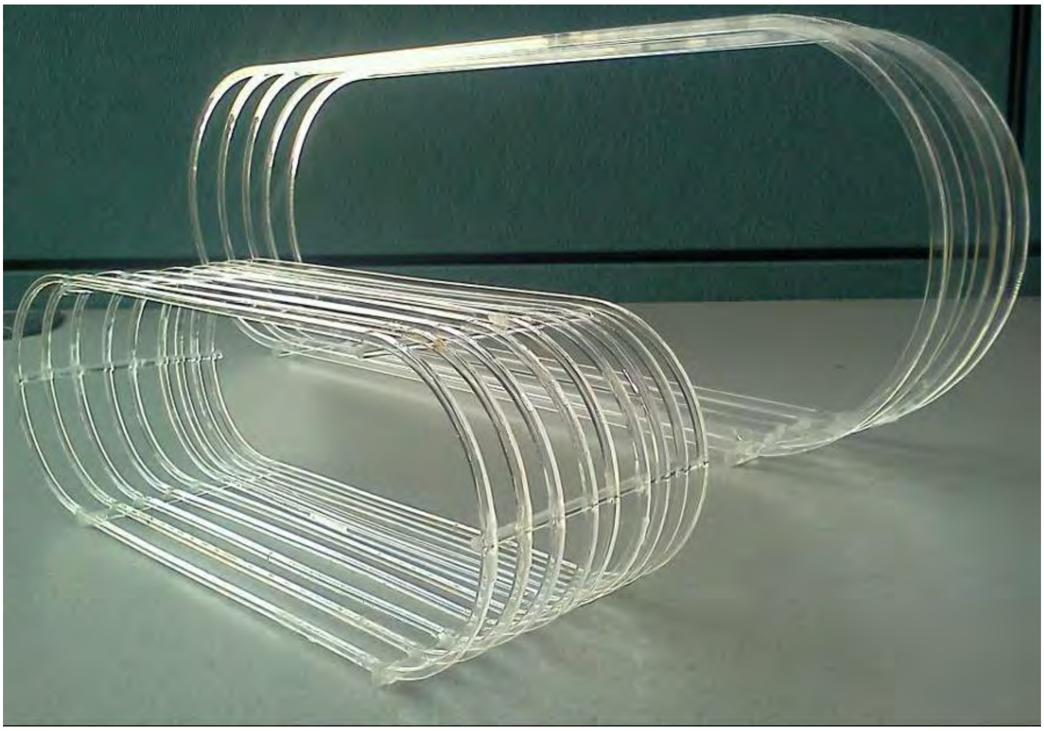

Figure 13: Physical mock-up.

7.1.2 RESULTS

It was observed that after several final presentations, most of the student's learning and understanding of how tools and methods come together to produce and develop a design are learned and mastered during this final presentation. Observing and evaluating other fellow student's similar outputs all together in one space has an overwhelming effect on deep understanding of design tool and design method integration. Tacit understanding of precision measurement, accuracy and control of a designs geometry is transformed into deep understanding of the responsibility a designer has to keep control over their design and design process.

8.0 HOW DOES COMPRESSION LEARNING BENEFIT STUDENTS?

By making room in the curriculum for new content and skill mastery subjects from other related areas of design, business, social science and engineering disciplines, compression learning allows room for curriculums to evolve and include these new areas of study and skill mastery for the student studying design. The benefit of bundling efficiently several subjects together into one course is shown by a marked increase the comprehension and understanding of the relevancy of the concepts taught. This method makes connections between the subjects and better prepares the student to use and apply the knowledge and tools to more efficiently solve design problems in the future.

Compression learning accelerates the learning of the behaviors and workflows that professional designers use in their everyday work lives. Mastering concepts in design integrity, precision measurement, precision translation, data integrity, surface integrity, data synthesis, data divergence and data convergence are difficult concepts for design students to understand, and are best learned by exploring them through project based learning. All of these concepts can be mastered more quickly by utilizing compression learning. It has been observed that students who take traditional core curriculum product design courses in isolation from one another (i.e. CAD or materials and processes etc.) find it difficult understanding how one tool or process relates its result with another tool or process later in concept development.

One of the ways hiring managers measure the amount of potential in a prospective designer is by the number of fully realized and completed projects in their portfolio. The more their portfolio can illustrate a variety of problem solving and successful design outcomes, the better the chance they have of obtaining their first professional full time position. In order to raise the number of design outcomes in the portfolio, design tools and skills must be learned and mastered earlier in the education curriculum. Compression learning is useful in achieving this goal.

9.0 CONCLUSIONS

Professors, lecturers, instructors and mentors are encouraged to apply compression learning to the subjects they teach. All sub disciplines of Design can potentially benefit from this method. Unfortunately not all that study and receive a degree in design will go on to become professional designers. Fortunately however, compression learning is designed to allow more content to be learned and absorbed in a given curriculum which can then also be applied outside of a career in design, thus providing a better value to the student pursuing and investing in a product design degree.

Statistical analysis of compression learning is unavailable for now. The only known metric for measuring compression learning's potential is that of: feedback from graduated students who are now working in industry, the registration popularity of the classes that utilize compression learning and from professors who teach students later in the curriculum who comment on the student's preparedness for the classes they teach.

This method has not yet been shared, adapted or used by others in product design education and is intended as an initial phase one release of the findings. Others may experiment on their own to adapt the compression learning methods as they see fit in their own pedagogical research projects.

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