Compression Learning for Product Design Education: Research and new methods in design education

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 design, visual design 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.
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 among others 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 increased 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 include these implications to the scope of their design work, 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 publically funded national university of science and technology as well as a private design college. The national university offers a 4 year
Bachelor of Science degree in design, and the private design college offers 3 year associates degree in industrial and information design. Both schools are located in Seoul, South Korea.

**Changes in student’s needs and 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 in the developed and increasingly the developing worlds, 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 smartphone technologies, students are able to increase their interactions outside of the classroom. Their capacity to learn from one another has dramatically increased as a result. As new design research methodology makes its way into product design curriculums, students are able to use these technologies to augment their projects and interactions while learning in teams outside of the classroom. The sharing of data and research in the beginning of projects becomes more viral, and less time is used in class updating team members on what research data each has collected since the last class meeting. This leveraging of smartphone, 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.

**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 behavior 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.

**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 design skill and tool mastery of traditional design learning content when fused with design research methods needs earlier introduction into design education curriculum. As noted in their paper, Strausse and Arnold stated, “The future of design research lies in creating new methodologies to solicit unbiased responses from people for the purposes of understanding their perceptions, perspectives and behaviours. Research methodologies focused on providing insight into the ideation phase of design show the most potential for growth in the coming years” (Strausse, Arnold, 2009). 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 and sophisticated 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. By year two of the research in this paper, it was found that it was possible to introduce: traditional drafting (T square and triangle), AutoCAD 2D and 3D CAD in a single course to first year level students. By year three of the research, a physical mock-up based on the 3D CAD model was added to complete the learning loop from traditional drafting methods to computer model to physical mock-up, all within 16 weeks. Learning tools, skills and design process methodology together helps make better sense of the “why” and the “how” modern, often times digital 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.

The premises of compression learning - applied theory
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 three ontological areas of academic research: Machine learning/data compression, Boolean algebra and Procedural learning theory. These subjects exist in the realms of computer science/artificial intelligence, constructive solid geometry (csg) and psychology respectively. Each area of research contains a variety of concepts that are applied to compression learning.

In the realm 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 in product design education with that of data compression and machine learning, allows the product design educator to combine the most critical learning concepts (i.e. compressed data) in each individualized course (i.e. raw data), 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 (primitives) and combining them cleverly using Boolean union and intersection connectors, only the essential elements that are necessary in a particular design process workflow remain. Compression learning includes only the essential elements that are necessary to understand the broader overview and strategy of design process workflow. See figure 1 below.

![Diagram](image.png)

*figure 1. Source: Author*
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 priming 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 judgement 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 design form factor 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. Understanding how tools and methods integrate to arrive at a design solution gives the students a higher quality, more comprehensive cognitive ability to address problems in design communication later as the complexity of problems increase.

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. In recent years it has been developing its graduate schools to build new programs in IT design, environmental design and the nano/bio tech design sector for Master and PhD levels. 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. The class offerings were created by the design department administration to offer 3rd year level students the opportunity to develop design concept skills in an English speaking environment. 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 domestic national market to understand a foreign market, its users and their problems.

In order to create context, the class is first introduced to what the class’s content will not include. Product design as a discipline covers many aspects of the design development process and the reality that designers are rarely able to work on the entire process from research to production is made clear on the first day of class via lecture and diagramming of the entire design development process. Concept design 1 does not include physical modelling and prototyping, and emphasizes design research techniques. (see figure 2 below)
figure 2. Source: Author
Concept Design 1 (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:

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

1. Team building is the first class exercise done together to establish the class into teams of 4 to 5 members. In order to reflect the reality of the professional workplace, grouping the students into teams by the instructor allowed for the most diversity and randomness among students, but not the best synergy. Allowing the students to form into groups on their own accord without direction from the instructor lead to teams generally divided along gender lines, but with much more synergy as the students formed groups with friends or others they felt comfortable with.

2. Social networking and project communication among team members was established during the first week using Facebook as a tool to facilitate member communication during the research phase. The teams created Facebook groups and were tasked with generating a team identity and group page. The teams worked online outside of class together to generate logo designs that reflected their team values and focus towards their user target. This exercise brought increased value to their project communications later in the semester.

3. Design Research, data collection and problem identification were the focus of the first 8 weeks of the semester. Students were encouraged to utilize the capacity that their group has to utilize the power of the internet to collect data. Divergent thinking is the prevailing directive to collect as much relative data on any target relating to the three phases of design research: culture, market and user. After each phase, a formal presentation is given to the entire class to share what they discovered as well as learn from each other’s research. In the culture phase of research, the students investigate contemporary trends in: economy, religion, language, cuisine, education, transportation, lifestyle and technology among others. The second phase of research covers market data: (high end vs. low end market segmentation, shopping environments and technologies, payment and transaction methods, online experience vs. traditional market experience, branding, advertising and business modelling. The third and final phase of design research is the user: daily life, family, job, stress levels, groups vs. individual, thinking patterns, needs and wants, age stratification, statistics etc. Once all data is collected and presented, the importance of moving the collected data from the digital realm and externalizing it in various physical forms that it can be manipulated and combined creatively is next. A number of brainstorming sessions were completed to look at the data from different perspectives and identify new problems and possible solutions. These sessions were combined with small group and entire class presentations along with Q&A sessions to develop critical thinking skills.

4. Design research summary and a problem identification list are combined into a final research presentation that is given for midterm grading credit. Convergent thinking is leveraged to edit out problems that are not worth solving and identify which problems are the most pressing to solve. Students are encouraged to summarize all of the previous research data and provide a list of unique problems they have identified. Storytelling methods and techniques are shared with students to enhance the interest, chronology and impact of their midterm presentations.

5. Presentation skill building is practiced in a variety of settings and languages. Use of Korean and English language presentation is alternated on a weekly basis to
allow students to feel comfortable understanding and communicating with each other in their native language as well as a second language. The semester begins using the Korean language, but once students are familiar with each other in their respective groups, English language is introduced to challenge them to improve their communication skills. Presentations are practiced in informal team settings, informal class settings, formal class settings as well as informal one on one sessions with the instructor.

6. After the midterm presentation, the class shifts from team focused work to individual focused project work. This allows for a balanced approach to developing both team and individual skill sets. At this point in time, each student has selected a problem to solve and begins to sketch out ideas and solutions. It was observed that after the midterm higher levels of trust, respect and synergy were present among students and faculty. This increased engagement is then tested by giving the students more individual autonomy and responsibility to move their respective projects forward independently. The students still meet in their teams during weekly class time, but class time is devoted to one on one reviews with the instructor.

7. Utilization of 2D and 3D CAD skills are now introduced into the project workflow after a sketch concept solution is accepted. It has been discovered through surveying that the students possessed a variety of proficiencies on a number of design software packages, both 2D and 3D (AutoCAD, 3D StudioMax, Alias, Rhino3D, ProEngineer). Rather than narrowly defining the tool set for the project, the students are encouraged to use what they know in order to develop their concepts. If they do not have a certain level of 3D cad skill, they are encouraged to use the project to help develop the skills they need to learn but do not yet posses. This approach has proven to dramatically improve CAD skills. CAD skills are not taught specifically in this class, but are required to utilize in order to develop concepts and communicate form factor and environmental contexts of solutions.

8. Art direction skills are introduced at the 13th week of the semester. In order for students to understand the need to separate the messiness of concept development from the organization of communication and presentation, they are required to begin to arrange their project files and think about how to tell a story with all of the data and information they have collected and created. A series of A1 size digital layouts are reviewed over the next 2 weeks to craft a narrative that accompanies their concept. Students are encouraged to regroup in their teams to prepare for the final presentation. Each team is required to prepare a presentation that summarizes the entire research and problem identification phase of their time together as if they were a professional consulting group. They are to explain to their audience why they chose to solve the problems they discovered and each team member is given time to present the details of their individual project solution following the final research presentation.

9. Storytelling skills are meshed with both the team’s final research presentation and individual concept presentations. Students learn how to prepare and present compelling and convincing design concept presentations. Learning properly how to summarize research, introduce solutions and then detail each individual project using both digital media and printed project panel media are rehearsed before giving the final presentation. Learning how to engage the audience and stimulate curiosity through storytelling are stressed in order to promote active Q&A by the audience. Students in the audience are evaluated on their ability to actively engage the presenters and provide critical feedback and ask questions relative to the presentation.
10. Team vs. individual skill building is addressed throughout the semester in a variety of situations. Students learn how to identify and leverage each situation they encounter during a concept development project. The goal is to get the students to understand their own shortcomings either as an individual designer or in a team setting.

11. Final concept presentation is the basis for most of the student’s semester grade. Team skills are measured by the final research and problem identification list, individual skills are measured during the individual concept presentations. (see figures 3 and 4) Presentations are given in English and bring together all of the semesters learning to reveal final solutions. Seeing all of their semester’s efforts come together to support the team’s effort to design and communicate to an audience of peers, students obtained a broad overview and understanding of design process that comes with 16 weeks of hard work using a variety of design methods, skills and tools.

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 the students 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.

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 application in design.

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 into the class pedagogy in order to promote deep level knowledge of methods and tools as opposed to mere superficial learning of procedural steps.

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. (see figure 5)

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:

1. Traditional 2D drafting techniques (T square, triangle, orthographic projection, triangulation)
2. 2D AutoCAD drafting techniques
3. Rhino 3D CAD modelling
4. CAD model visualization
5. 3D CAD drafting and drawing output
6. Physical prototyping based on 3D data base
7. Final project presentation skills
1. Traditional 2D drafting techniques are introduced in the first 4 weeks. Students are tasked with: learning how to set up a drafting board, tool use, tool care and are taken through a series of exercises that stress aspects of triangulation, orthographic projection, precision measurement, accuracy, craftsmanship, lettering and effective drawing communication. Due to the now popular use of computer drafting, this virtual lost art in traditional design training is deemed necessary to still be included as it is still used informally in many sorts of design communication scenarios where quick delineation of design intent is necessary to communicate to a number of associates, colleagues and co-workers.

2. AutoCAD 2D drafting is the next 4 week module. Students move to the computer lab where they are introduced to AutoCAD drafting software. Enough navigation, menu and tool use is introduced to repeat the same assignments during the traditional drafting module of the course. It is this repeating of the same design but with different tools and methods where the course leverages the teleological and repetition priming aspects of compression learning. One of these assignments is used for their midterm exam which accounts for 20% of their grade. Once the students are
able to produce competent 2D drawings in both digital and printed formats they are ready to be introduced to the 3D CAD area of design tool and methods workflow.

3. Four weeks of 3D Rhinoceros CAD follows the AutoCAD 2D drafting module. Importing their previous midterm AutoCAD .dwg data files into the program extends repetition priming and teleological learning concepts and gives the students and immediate overview of design process seeing their previous AutoCAD drawing imported into a 3D CAD program. Over the course of the next four weeks, students build a 3D CAD model from their midterm 2D data file. At this point, they have replicated the same design using 3 different tools, methods and workflows. It was observed that by focusing only on tool learning and method application and avoiding introducing any creative concept application, students are able to learn more quickly and feel more confident with using the tools, methods and processes. By understanding how the tools logically fit into the design process and how they are used together to develop design solutions, students increase their comprehension of the workflow process. Students benefit also by disseminating knowledge quickly and completing the exercises together by working in small informal groups during the class time.

4. CAD visualization although important to product design process, has become redundant in its ability to simulate photorealism through the development of rendering software. This part of the design workflow learning now takes just a few hours to teach and learn. Hypershoot and Keyshot rendering software are used to visualize the 3D model in a variety of materials and lighting conditions.

5. Model drawing output is also important to understand when interfacing with other professionals in the design process loop. Many 3D modelling software packages now make this as easy as pressing a menu button (Rhino 3D, Pro-Engineer, Solidworks etc). Students plot their drawing in a variety of sizes which helps the student understand the concept of scaling and related communication issues.

6. Physical prototyping of the Rhino 3D database file is next. The students are tasked with delivering production drawing they have output from the Rhino-3D program and delivering it as well as the .3DM file to the school’s laser cutting shop. From there students are responsible for getting their parts fabricated and assembled into a physical mock-up. Skill building in matching the dimensional precision of the drawing to the physical model is stressed and is part of the final grading evaluation.

7. Final project presentation skills are developed through the assembly of all of the previous semester’s projects for critique. (see figures 6 thru 13).
figure 6. Traditional drafting
Source: Author

figure 7. AutoCAD 2D
Source: Author
Figure 8. AutoCAD import to Rhino 3D
Source: Author

Figure 9. Rhino 3D CAD model
Source: Author
figure 10.  CAD visualization

Source: Author

figure 11.  RhinoCAD model drawing output

Source: Author
figure 12. Laser cutting
Source: Author

figure 13. Physical prototypes
Source: Author
It was observed that after several final presentations over the course of 3 years, 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 design’s geometry is transformed into deep understanding of the responsibility a designer has to keep control over their design and design process.

**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 behaviours and workflows that professional designers use in their everyday work lives. By learning to combine several skills and tools simultaneously on a given project, students accelerate their maturity towards being able to design as a professional would. 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 comprehensive the project is in its creative inclusion of processes and methods, the more qualified the candidate, and the better a hiring manager can evaluate the candidate. More portfolio projects equal more opportunities to refine skills and increase design quality. Newly graduated designers must show in their portfolios how they can understand and manipulate concept, material, process, user, data and system. 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.

**Conclusions**

Industrial Design professors, lecturers, instructors and mentors are encouraged to apply compression learning to the subjects they teach. As stated, it can be used to combine a variety of traditional core subjects that normally taught as standalone classes. The more arbitrary the combination of core and new subjects, the more unique the blend of learning is offered, and in the end, more beneficial to the student.
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.

The broader scientific results and impact of compression learning for product design remain to be realised. For now there is a high confidence that compression learning for product design will deliver an improved teaching methodology that allows students to more quickly comprehend and master design skills, tools and concepts in order to learn more content that will broaden the value of their degree.

Statistical analysis of compression learning is unavailable for now. The method will need other instructors and educators to experiment with its merits and potential utilizing design thinking methodology. 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 other 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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