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Message from the Chair

Nick Bertozzi
Daniel Webster College

The previous two EDGD chairs, Dennis Lieu and Kevin Devine, along with the Director of Membership, Diarmaid Lane, have emphasized the importance of attracting new members to EDGD. In addition to scholarships and reduced Midyear registration fees for first-time attendees, a YouTube video, "*Why you should join the Engineering Design Graphics Division!* ", was created and a link posted on the EDGD homepage. An attractive informational flyer was distributed at the ASEE Summer Conference informational session, and a coffee/donut session was held in Indianapolis and a cookies/soft drinks session was held in Seattle. In an effort to encourage anyone who might be reading this message to consider getting involved with EDGD, I would like to describe the tremendous influence and impact my EDGD colleagues have made on my students and College, and on me personally.

In my first engineering job I worked in the HVAC group of a consulting company that was designing Hyatt Regencies and Holiday Inns for Kuwait. There were no CAD systems at that time. I like to tell my students that I spent 38 percent of my time drawing lines, and 31 percent of my time erasing lines! Later, in 1986, while I was teaching in a two-year engineering transfer program at Daniel Webster College (DWC), the adjunct instructor who was teaching the engineering graphics course decided to retire. I wasn't able to find a replacement instructor in time, and so decided to teach the course myself. We obtained AutoCAD R2.1 and installed it on Rainbows with 256 K of RAM (wow!) At that time AutoCAD required inserting 5.25" floppies for certain commands! It was awkward, but a huge step forward from drawing on the board. Layers were wonderful as was perfect lettering every time.

I had recently joined ASEE, and since I was now teaching engineering graphics, I listed EDGD as one of my divisions and started receiving and reading the EDG Journal. In August 1996 I attended a NSF Concurrent Engineering Design Workshop at the University of Texas at Austin led by Ronald Barr and Davor Juricic. This workshop demonstrated the power and potential of the concurrent engineering paradigm. As a result of this workshop, in 1998 a three-semester engineering design sequence was introduced in DWC's two-year engineering program.

The sequence was well received by the DWC engineering students, and in 2005 the College introduced BS degrees in both aeronautical and mechanical engineering. These programs both contain a five-semester design sequence. Engineering graphics and concurrent engineering are developed and exercised through-out the curriculum.

My first EDGD midyear meeting was in 2002 at Berkeley. By attending the presentations and through conversations with the participants, I was able to gain insight

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on how to improve the engineering program at DWC. I was amazed at the friendliness and openness of the EDGD members, as well as the humor of the site chair, Dennis Lieu.

The first midyear in which my students presented was in 2004 at Williamsburg. When we first arrived and walked through the door, Pat Connolly immediately engaged my very nervous students to welcome and encourage them. Many others did the same throughout the conference including Larry Goss. My first time presenting a paper at an ASEE summer conference was in 2005 at Portland, Oregon. Kathy Holliday-Darr and Judy Birchman were extremely welcoming, helpful, and encouraging.

At the midyear in 2007 at San Diego, Frank Croft and Ron Paré encouraged me to be the EDGD program chair for the 2008 summer conference in Pittsburgh. I never would have thought to try to do something like this had it not been for the supportive culture that permeates the EDGD. There are too many EDGD members to mention all those who have encouraged my students (La Verne Abe Harris, Ted Branoff, Marie Planchard, Nancy Study, Norma Veurink, Tim Sexton, Dennis Lieu, and Jon Duff are just a few). At the midyear meeting in 2009 at Berkeley, Holly Ault encouraged Jen (McDonald) McInnis to visit WPI. Jen then worked as a TA for David Planchard while attending graduate school at WPI, is now back as a professor at DWC, and will be site co-chair for the 71st midyear at DWC in October 2016.

Robert Chin provided great advice and support during my six years as director of communications, and without the encouragement and mentorship of Kevin Devine, I never would have considered serving on the EDGD executive committee.

I hope these comments convey the great blessing that EDGD has been to the DWC students and programs, and to me personally. For anyone who is looking to plug into an ASEE division, I wholeheartedly recommend membership and participation in EDGD.

In closing, I would like to convey congratulations to those who received EDGD awards at the 2015 summer conference in Seattle:

- The Chairs Award – Holly K. Ault, Linjun Bu, and Kejiang Liu
- The Editor’s Award – Petros J. Katsioloudis and Vukica Jovanovic
- The Distinguished Service Award – Dennis K. Lieu

Also, congratulations to Mike Stewart who is retiring after 44 years of teaching!

Site chairs Heidi Steinhauer and Lulu Sun, and program chair Diarmaid Lane have done an outstanding job organizing the 70th midyear conference which will take place January 24-26, 2016, in Daytona Beach. (http://commons.erau.edu/asee-edgd/conference70/)

I look forward to seeing you there!

Nick Bertozzi

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Message from the Editor

AJ Hamlin
Michigan Technological University

For the past three years I have served as the Associate Editor of the *Engineering Design Graphics Journal* and I am excited to be transitioning into my new role as Editor. I am pleased to present my first issue in this new capacity which contains two articles.

Karl Hurn and Ian Storer of Loughborough University, present a pilot project that they have undertaken with industrial design postgraduate students in which they use mashed aesthetics to improve the quality of designs early in the idea generation phase of the design process.

Riccardo Metraglia, Valerio Villa, Gabriele Baronio, and Riccardo Adamini of the University of Brescia, present the results of their investigation on the influence of prior graphics experience on the self-efficacy and performance of first-year engineering students in an introductory engineering graphics course.

I would like to thank all the reviewers as they take time to carefully consider each submitted manuscript and provide thoughtful feedback to the authors. I wish to thank the members of the Engineering Design Graphics Division for their support and guidance during my transition to editor and I especially wish to thank Bob Chin and Nancy Study who have been invaluable.

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EDGD Calendar of Events

Future ASEE Engineering Design Graphics Division Mid-Year Conferences

70th Midyear Conference - January 24-26, 2016, Daytona Beach, FL.
Site Chairs - Heidi Steinhauer and Lulu Sun. Program Chair - Diarmaid Lane.

71st Mid-Year Conference – October 16-18, 2016, Nashua New Hampshire.
Site Chairs – Jennifer McInnis and Tim Kostar. Program Chairs - Aaron Clark and Jeremy Ernst.

Future ASEE Annual Conferences

Year	Dates	Location	Program Chair
2016	June 26 - 29	New Orleans, Louisiana	Heidi Steinhauer
2017	June 25 - 28	Columbus, Ohio	
2018	June 24 - 27	Salt Lake City, Utah	
2019	June 16 - 19	Tampa, Florida	
2020	June 21 - 24	Montréal, Québec, Canada	
2021	June 27 - 30	Long Beach, California	
2022	June 26 - 29	Minneapolis, Minnesota	
2023	June 25 - 28	Baltimore, Maryland	

If you're interested in serving as the Division's program chair for any of the future ASEE annual conferences, please make your interest known.

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The Distinguished Service Award

The 2015 Distinguished Service Award (DSA) recipient is Dennis K. Lieu of University of California at Berkeley. The DSA is the highest award of merit given by the Engineering Design Graphics Division. It recognizes the significant contributions of the recipient to the Division in terms of leadership, authorship, or support.


[1]

The awardee is recognized with a framed citation or plaque, which is presented by the Division Chair or their delegate at the Annual Conference Awards Banquet. Following the presentation, the recipient may address those assembled.

The award description can be found at:
http://edgd.asee.org/awards/dsa/index.htm


[2]

A complete list of awardees can be found at
http://edgd.asee.org/awards/dsa/awardees.htm

[1] Engineering Design Graphics Division Member, Sheryl Sorby, introducing the 2015 DSA recipient.
[2] Lieu delivering his DSA acceptance remarks.
[3] Sorby presenting the DSA plaque.

Photos by ***Theodore Branoff***


[3]

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Sheryl Sorby's Introduction of DSA Recipient Dennis Liu

I was honored to be asked to introduce this year's recipient of the Distinguished Service Award, but then I realized, I'm probably his only friend here tonight, so it all makes complete sense. Kidding. I am very pleased to present a most worthy candidate for the DSA-- Dennis Lieu.

In 1994, we got a grant to host a workshop for graphics faculty at Michigan Tech. the focus of the workshop was—you guessed it—developing 3-D spatial skills. The workshop was a marginal success and as part of our grant-sponsored follow-up activities, we were to host a reunion dinner at the next EDGD midyear meeting. Dennis showed up for the dinner, even though he had not been part of the workshop. Being the polite Midwesterner that I am, we welcomed him to the table and proceeded to have an excellent meal. About half-way through dinner, Dennis looked at me and said "I'm not supposed to be here am I?" We all laughed and said he was most welcome to be there—NSF could afford one additional person at the table. This was the first time I met Dennis and the first of many meals we have shared over the years. I think that may have been his first time attending a mid-year meeting—it was my second or third time.

Dennis has always been interested in helping students learn graphics and he's really a technology junkie. He developed a software tool at about that time to help students learn about orthographic projection and other difficult concepts. The software was published along with a McGraw Hill text and included videos and animations—at a time when educators were just beginning to experiment with this type of tool to further student understanding. Dennis was really at the vanguard in technology-enabled education, especially in graphics. And he carries this forward even today. A few years ago, when the iPad was about 6 months old, Dennis was trying to figure out how it could be used in graphics education. He developed some cool things for the iPad, but the difficulty was in the adoption. Dennis was probably before the times on that one—people just weren't ready for it.

Back in about 2000, Dennis put in a bid to host the midyear meeting at Berkeley. In 2002 he hosted one of the most successful midyears in recent history (not more successful than the one in Houghton, though) and he followed up with an encore performance in 2009. Who can forget his hilarious presentations inviting us to the Berkeley mid-years? In his first invitation, he admonished us to make sure we made our plane reservations for Oakland, California and not Oakland, Michigan. He then proceeded to show a series of slides comparing and contrasting the two cities. Most of the pictures of Oakland, MI had snow or blizzard conditions and the pictures of Oakland, CA showed sunny warm days and beautiful scenery. For the second Berkeley midyear, the invitation included numerous options for things to see and do in San Francisco. I'm

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not sure there were any takers for the Asian, transvestite, strip show in Chinatown, but a number of people did partake of the wine country tour.
Personally, I'm looking forward to the next Berkeley midyear just so I can sit through Dennis's invitation. He truly has a creative and humorous outlook—his mind does work in mysterious ways.

In 2001, I was approached by Jim Devoe from Delmar Publishing with a wild and crazy idea. Dennis had pitched an idea for a new type of graphics book to him and they wanted me to help co-author it. If hindsight is 20-20, I should have run away from that, but I'm just not that smart, I guess. So we persevered, and got to work. We roped many of you sitting in this room tonight with contributing to the text as well. Now that the ink is dry, I can say that I have had the good fortune to work closely with Dennis through the writing of the Sorby and Lieu textbook—I mean the Lieu and Sorby textbook. His creativity and innovative thinking were an asset to the development of the text and my totally unbiased opinion is that the book is one of the best on the market today. LOL.

In closing, for his scholarship, his creativity, and his dedication to the Division, I think that Dennis Lieu is a most worthy recipient of this award and I am honored to be here tonight introducing my dear friend and colleague.

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Dennis K. Lieu's DSA Acceptance Remarks
ASEE Annual Conference
Seattle, WA, June 14-17, 2015

I am flattered and moved, almost beyond words, to receive the EDGD Distinguished Service Award. I know many of the past recipients of this award, and it is a true honor to be counted among them.

My career in engineering design graphics has been quite a journey, and one that I'm sure is not over yet. As most of you are aware, I'm sort of an oddball. Most of you studied, and now teach, graphics as your primary profession. For me, graphics was not my original main area of expertise, but I came to enjoy it more than anything else I did at the University. I happened upon it almost by accident. When I was an assistant professor 25 years ago, I decided that I needed a career plan. It was a time soon after ABET had eliminated engineering graphics as part of its list of required subjects, and academicians who were involved with graphics were considered to be headed toward a dead-end career. Some people think with their heads, other with their hearts. I tend to think a lot with my stomach, so please excuse the following analogy. Planning a career is like planning a diet. To live a long, healthy life, one must include the right foods. But if engineering academia is the buffet of life, EDGD is a big plate full of bacon. Now I love bacon, but 25 years ago, bacon was considered to be bad. Despite the fact that it tasted great, it was also loaded with saturated fat, salt, and preservatives. My colleagues at the University advised me, "Don't touch the bacon, it will kill you." But along came EDGD, who whispered to me, "Come eat bacon with us." Engineering graphics then started to evolve in a way that few people anticipated. The field changed and became different, more exciting and useful than anyone could ever imagine. At the same time, it was discovered that perhaps bacon really wasn't that bad after all. In fact, bacon every so often could actually be good. Everyone can use a little bacon, sometimes a lot of bacon.

"Thank you" my friends and supporters: Sheryl, Ted, Aaron, Frank, Nancy, Holly, my students, too many others to mention, and this entire graphics community. Thanks for the support, good times, friendship, and the bacon. Most of all, "thank you" to my wife and kids, who have put up with my many antics for so many years.

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The Editor's Award

The 2014 Editor's Award awardees are Petros J. Katsioloudis and Vukica Jovanovic of Old Dominion University for their paper entitled, "Spatial Visualization Ability and Impact of Drafting Models: A Quasi Experimental Study." Their paper was published in volume 7, number 2 of the Journal and can be found at: http://www.edgj.org/index.php/EDGJ/article/view/420

Editor's Award recipients, Petros Katsioloudis (c) and Vukica Jovanovic (l), accepting their framed citation from EDGJ editor, Robert Chin (r).

The Editor's Award was established to recognize the outstanding paper published in the previous volume of the Engineering Design Graphics Journal. The recognition includes a framed citation and a cash award and is presented during the following Annual Conference.

The award description can be found at http://edgd.asee.org/awards/editors/index.htm

A complete list of awardees list can be found at http://edgd.asee.org/awards/editors/awardees.htm

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Officer Nominees

According to Article IV: Elections and Succession of Officers, Section 1, paragraph 1d of the Division by-laws (http://edgd.asee.org/aboutus/edgdbylaws.htm), not later than February 15, and returnable before March 15, the Secretary-Treasurer shall mail to each member of record (as provided by the Journal Circulation Manager-Treasurer) of the Division a ballot bearing the slate submitted by the Nominating Committee together with additional names presented by petition. A candidate receiving the largest number of votes for the office sought shall be declared elected. The ballot shall be designed to facilitate return mailing and bear the name and address of the chair of the Elections Committee, the Division Vice-Chair.

The Division members that follow comprise the slate of candidates.

Robert A. Chin
For Vice-Chair

Robert A. "Bob" Chin is a member of the Department of Technology Systems faculty, College of Engineering and Technology, East Carolina University, where he has taught since 1986. He just completed his second term as the director of publications for the Engineering Design Graphics Division and as the *Engineering Design Graphics Journal* editor. Chin has also served as the Engineering Design Graphics Division's annual and mid-year conference program chair, and he has served as a review board member for several journals including the *EDGJ*. He has been a program chair for the Southeastern Section and has served as the Engineering Design Graphics Division's vice chair and chair and as the Instructional Unit's secretary, vice chair, and chair. His ongoing involvement with ASEE has focused primarily on annual conference paper presentation themes associated with the Engineering Design Graphics, the Engineering Technology, and the New Engineering Educators Divisions and their education and instructional agendas.

Theodore Branoff
For Director of Programs

Theodore Branoff, Ph.D. is a professor and chair of the Department of Technology at Illinois State University. He taught engineering graphics, descriptive geometry, and constraint-based solid modeling courses at North Carolina State University for 28 years before moving to Illinois State University. Dr. Branoff was previously employed with Measurements Group, Inc. as a draftsman and with Siemens, Switchgear Division as a specifications draftsperson. Along with teaching courses in engineering graphics, he has conducted CAD and geometric dimensioning & tolerancing workshops for both high school teachers and industry. He

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has also authored textbook chapters on conventional tolerancing and geometric dimensioning and tolerancing and authored a textbook on interpreting engineering drawings.

Dr. Branoff is currently a member of the Engineering Design Graphics Division of the American Society for Engineering Education; the Association of Technology, Management and Applied Engineering; the International Technology and Engineering Educators Association; the International Society for Geometry and Graphics; and Epsilon Pi Tau. He has served as Chair, Vice-Chair, Director of Programs, and Director of Professional & Technical Committees for the EDGD and as Co-Editor of the *Engineering Design Graphics Journal*. In addition, he served as president of the International Society for Geometry & Graphics from 2009-2012. In 2013 he was elected into the Academy of Fellows of the American Society for Engineering Education, and in 2014 he received the Distinguished Service Award from the Engineering Design Graphics Division of ASEE. In April of 2015 Dr. Branoff received the Orthogonal Medal for distinguished service in graphic science from the Technology, Engineering & Design Education faculty at North Carolina State University.

Diarmaid Lane
For Director of Membership
Diarmaid Lane received his B. Tech (Ed.) and Ph.D. in Technology Education from the University of Limerick in 2008 and 2011 respectively. He spent six years in the metal fabrication industry developing engineering craft based skills prior to pursuing his studies in technology education. He currently holds a faculty position at the University of Limerick where he teaches engineering graphics courses on undergraduate and postgraduate programs in technology teacher education.

Diarmaid has acted as program chair for both the 67th and 70th MidYear Conferences for the Engineering Design Graphics Division. He was been awarded the EDGD Chair's Award in 2010 and 2011, and the Oppenheimer Award in 2012 and 2014. His research interests are in the development of spatial cognition and graphical communication skills through freehand sketching.

If elected as membership officer in EDGD, his goal would be to further investigate the future direction of the membership. He would also reach out to researchers in other disciplines to become involved in the division by encouraging the development of working partnerships and ultimately further strengthen the role of engineering graphics educators within the engineering education community and beyond.

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Using Novel 2D Image Manipulation Methods to Aid Initial Concept Generation with Postgraduate Industrial Design Students

Karl Hurn and Ian Storer
Loughborough Design School, Loughborough University

Abstract

The aim of this paper is to provide educators and industrial design professionals with an insight into the development of innovative design ideation images manipulation techniques and, highlight how these techniques could be used to not only improve student ideation skills, but also as design enablers for a broader range of professionals working both inside and outside the creative industries. The review of literature highlights the changing role of the industrial designer through influencing factors such as increased involvement in upstream design activities and the 'maker movement'. The paper documents research conducted with postgraduate industrial design students in a specific year group within Loughborough Design School. The study is a pilot project with a small cohort of 29 industrial design postgraduate students which will form part of the ongoing pedagogic development of the skills required for the ever evolving discipline of industrial design. The study covers one academic semester, where postgraduate industrial design students were asked to use novel ideation methods to produce a range of aesthetic design directions for a communication device. The results of the research showed significant improvements in ideation workflow, the suitability and quality of the student's form generation, as well as the perceived quality of the final design outcomes.

Introduction

Industrial Design (ID) is defined by the Industrial Design Society of America (IDSA) as "the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer" (Industrial Designers Society of America, 2014). Within this broad definition, Tim Brown's T shaped designers' (Brown, 2009) are evolving in the rapidly changing product development landscape. The many disciplines involved in new product development have seen demarcation between roles blur and a post disciplinary model emerge where industrial designers have been introduced to more upstream activities and design tools have been introduced to "people who may have never thought of themselves as designers" (Brown, 2009 cited in Joore, 2010. p 200).

Review of Literature

Processes recently labelled as "Design Thinking" (Brown, 2009; Cross, 2011) have introduced designers to techniques formerly more common in business, marketing,

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advertising and social science domains (see the cross stroke of Brown's T shaped designer shown in Figure 1).

The opportunity to get involved in design is greater than ever before as design tools become more accessible (Winnan, 2013). With high quality Computer Aided Design (CAD) and tablet computer versions of formerly expensive design software available at low cost, potentially widening design participation (Hurn, 2013).

Manufacturing small components at home has become possible through 3D printing and small scale computer controlled milling machines, giving rise to a new designer maker movement that has a desire to better understand the upstream process of design (Anderson, 2012) and, as Casden puts it, *"is rebuilding American industry, one garage at a time"* (Casden, 2014.

Figure 1. Diagram of the modern industrial designers' skillset based on Tim Brown's "T-shaped designer."

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The changes to the design profession for existing designers, novice designers, hobbyists and stakeholders in the design of new products create new demands on design education (Lawson, 1990). Accommodating the cross stroke of Brown's T shape in an industrial design degree program with finite resources inevitably makes less time available for the development of the more traditional design skills of the vertical stroke. However, to test the outcomes of design research/design thinking processes, rapid solution visualization is still required. Illustration, prototyping, testing and refining of ideas into realistic solutions is still a vital role of the industrial designer (Brown, 2009). ID courses traditionally teach visualization techniques, however, against a background of compressed time to teach and learn these skills a different approach may be required. Initial steps towards this involve novel methods to increase the efficacy of teaching design visualization methods by linking sketching, CAD and physical modelling (Storer & Campbell, 2011).

Product aesthetics are considered a strategic tool in capturing consumer attention (Govers, 2004) and are an aspect of design that traditionally absorbed a significant proportion of an industrial designers' time. Crilly (2009, p. 224) considers the appearance of products to have "*a profound effect upon the way in which they are interpreted, approached and used."* However, it appears that aesthetics have received less attention from the proponents of design thinking. Tonkinwise (2011, p. 536) states that *"all attention being paid to design, whether researched or promotional is nevertheless missing a vital aspect of designing. Aesthetics are downplayed by 'design thinking'."*

The development of aesthetic sensitivity and an ability to create desirable objects is one of our goals in educating industrial designers. However great design is defined, it comes down to desirability, whether this is functionally, aesthetically, or culturally derived. Research into how to encourage and engrain these abilities in student designers has driven a number of educational strategies exploring design inspiration.
The authors noted the changing demands on the design education curriculum and propose a novel method to help develop aesthetic sensitivity and improve the speed and quality of initial concept generation.

Prior Research by the Authors

During the initial ideation phase of the design process, professional industrial designers use a variety of source images as a jump off point to feed the creative process (Hurn, 2011). Concept artist Scott Robertson cities the building of a visual library of resource

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images as an important skill for industrial designers to inspire and inform their form and styling development process (Robertson, 2012). Professional industrial designers might be expected to take this lead, or be provided with source material by Marketers or Brand Managers working for prospective clients. Either way, students are taught to mirror this process of physical mood board or online visual language wall creation to inform their ideation.

However, previous studies have shown that students collect these visual language image resources but that there is a disconnect in their application to the ideation process, meaning that students often do not use this resource and complete the task simply to gain an academic mark (McDonagh & Storer, 2004). Exposing designers to inspiration material has been shown to have both positive and negative results (Cai, Do & Zimring, 2009; Goldschmidt & Sever, 2010) in that it can lead to a wider range of potential solutions and at the same time potentially lead to plagiarising existing work. Research conducted by Cheng, Mugge and Schoormans (2014) on design fixation, suggests that the use of images hinders designers from creating original designs. However, designers continually absorb influences whether conscious or unconsciously and it would be very difficult to design anything without some reference to existing work. In this study, the work is directly created from existing design elements in an overt manner with the source material visible to all parties, however, the idea is that this will in turn be translated, transformed and built upon before the final solution is delivered.

There has been a continuing theme in the authors' teaching within Loughborough Design School to encourage student engagement with visual resource materials during the creative process. A method of understanding and decoding the semantic messages inherent in product form, the Form Analysis Criteria (Lawson & Storer, 2008) were introduced to a number of design practice modules over the last 10 years and used in this 2011 (McCardle et al., 2011) study to good effect. However the authors observed that there was a lack of depth in the students understanding of the semantic messages expressed by the product form.

A 2008 study within Loughborough Design School also found that students' lack of confidence in their sketching ability was creating a barrier to creativity, and hampering their ability to accurately depict form, texture and materials (Storer, 2008).

This new study conducted with postgraduate industrial design students within Loughborough Design School integrates the collection and collation of visual language images into the ideation process by encouraging students to manipulate and combine

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those images using image manipulation software to create high quality conceptual start points directly from those images. Therefore providing the threefold benefits of a) removing the disconnect of visual research and ideation, b) removing the initial sketching barrier to creativity for some students and c) allowing students to manipulate and understand high quality form, texture and materials through the direct use of those images.

To simplify the experiment postgraduate students were chosen as they should fall into the competent category of Dreyfus' five stage model of skill acquisition (Dreyfus,1986), hopefully removing the need to teach the basic techniques. Adobe Photoshop was used to facilitate the primary image manipulation as the students were all familiar with it and it is installed on the institutions design studio computers. In particular, the edit/transform and colour matching features are very powerful in Adobe Photoshop, allowing quick progress with these techniques.

A Mash-Up is defined by the Oxford English Dictionary (2014) as *"A mixture or fusion of disparate elements".* The music industry presents many examples of combinations of disparate elements being combined to explore new directions. In this case we are using it to describe the process of creating images of new objects by combining elements of existing images of objects. In a broader sense than the design industry, the term mash-up has been used for a number of years to describe the method of using image manipulation software such as Photoshop to create often comic combinations of film/TV characters, media celebrities and visual predictions of new automotive models.

The timely relevance of this approach as a design ideation tool is supported by the emergence of "mashed aesthetics" as a legitimate design direction within the design industry itself (Kaleidoscope, 2009). Mashed aesthetics refers to a recognized trend to reuse, combine and reinterpret existing historical designs, following on from, and reacting to "retro" design. Mashed aesthetic design can draw from different eras, product groups and disciplines, with designers "mashing" them together to create new and exciting design directions. Wanderlust, a US design trend forecasting consultancy, recently stated that *"in the post-post-modern design world, all form is fair game"* (Kaleidoscope, 2010.

Method

During an academic exchange to the Middle Eastern Technical University METU, Turkey in 2014, the authors demonstrated their novel mashed aesthetics image manipulation

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techniques to industrial design undergraduates. Figure 2 shows the example used, combining two typical streamlined vehicles to create an alternative universe land speed record vehicle, with the example being completed in 15 minutes. The level of realism achieved was high compared to the time invested; however the source images were in an advantageous orientation.

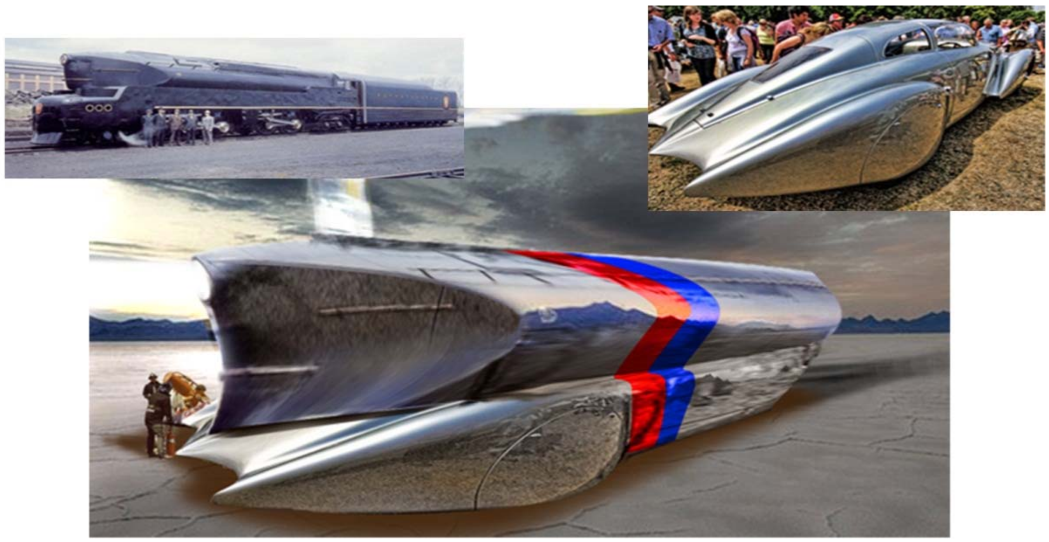

Figure 2. An example of the mashed aesthetic technique demonstrated at the authors' concept art workshop at Middle Eastern Technical University (METU) in 2014

Visualizing the same complex object using traditional sketching (shown in Figure 3) to a similar level of detail took forty minutes without any representation of material finish or environment. This technique, although purely two dimensional has the potential to expedite visual brainstorming prior to sketching or concurrently alongside sketching during the exploratory phase of form generation.

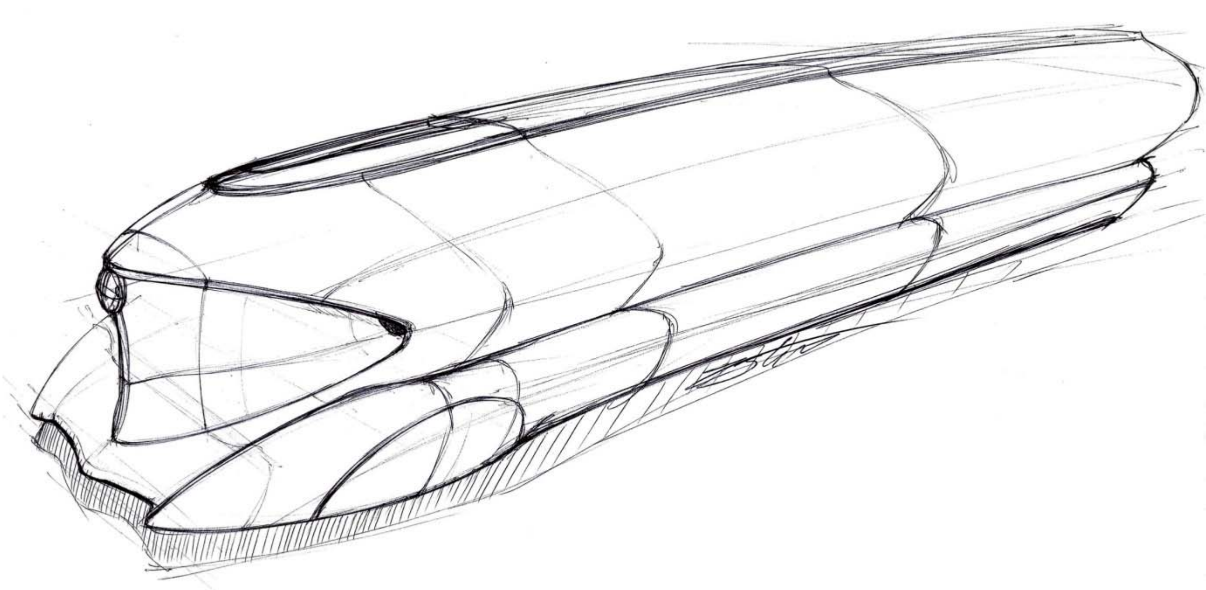

Figure 3. An example by the author of the same form as the METU mash-up example sketched over a 40 minute period

At Loughborough Design School, the Industrial Design Skills (IDS) module within the Master’s in Industrial Design program was introduced to facilitate the development of core skills such as design research, ideation, conceptual development, 2D visualization and 3D CAD modeling. The relatively small student cohort of 29 consists largely of international students from China with smaller numbers of students from Europe and the United Kingdom. Due to the small number of students participating, the project would be used as a pilot study to inform the author’s ongoing pedagogic research. The students were asked to create concepts for a communication device for a specific user of their choice. This involved defining the user, task, and environment (UTE) initially by conducting visual design research using the image gathering website Pinterest. Online versions of traditional mood boards were produced including images of likely scenarios, products, transport, architecture, etc. The students were also encouraged to choose unusual or challenging users and environments as a vehicle to provoke innovation. The students then received instruction on how to create mash-up visualizations’ in Adobe Photoshop as shown in Figure 4.

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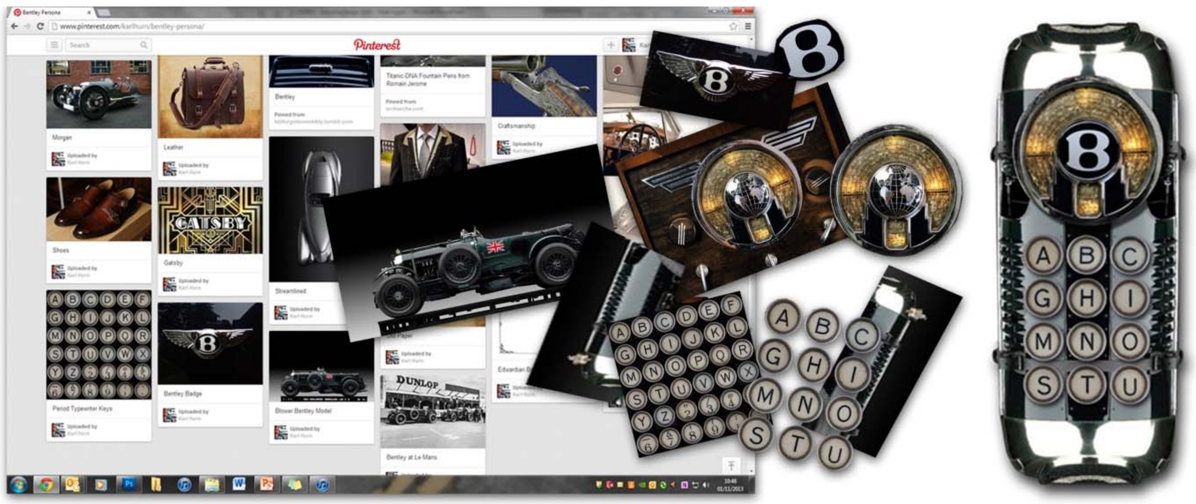

Figure 4. Example by the author of extracting form and visual language detail from Pinterest resource to create a novel product.

To gauge the impact of the initial mash-up process, after a 20 minute demonstration by the authors the master's students were asked to create a mash-up of a communication device from the same image resources used by the author in Figure 4. The authors were greatly encouraged by the examples produced by the students as shown in Figure 5. In the authors view; they show a high level of industrial design form giving, diversity, and design detailing.

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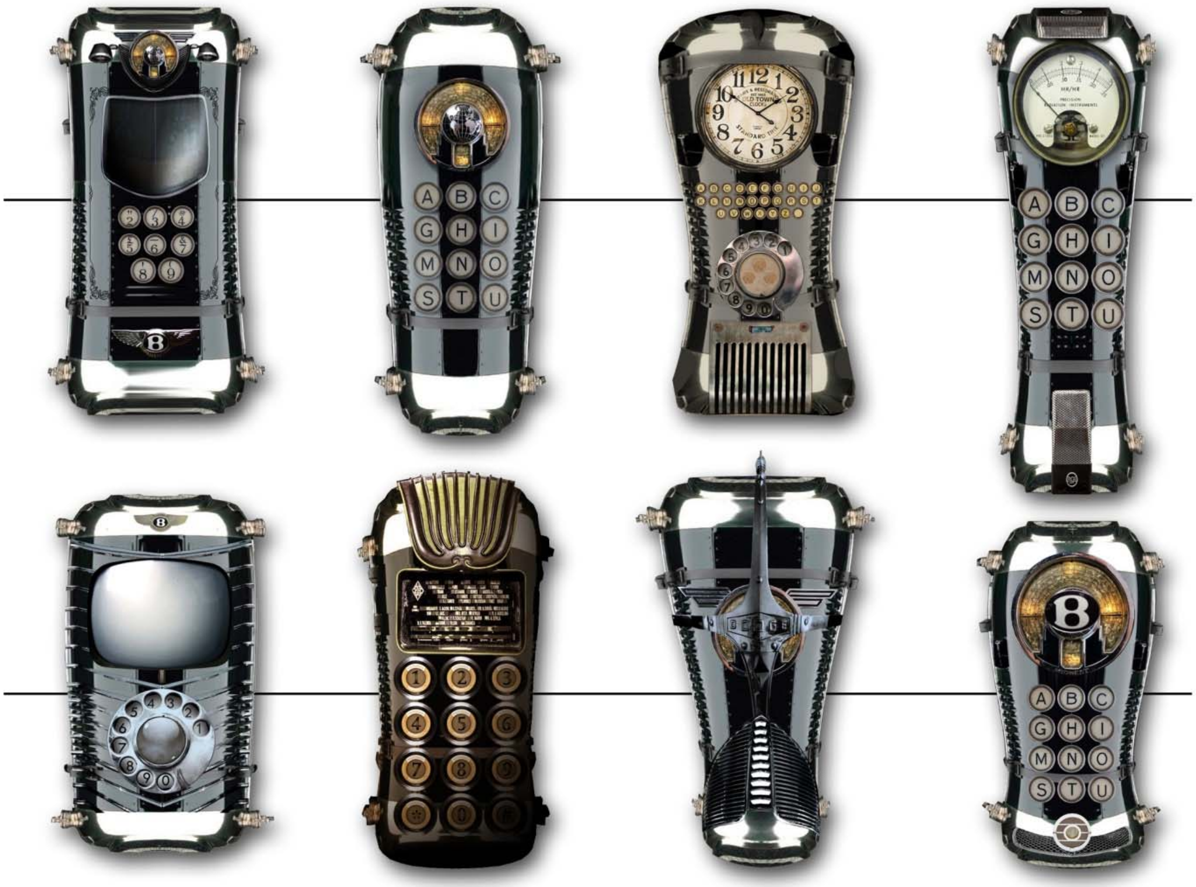

Figure 5. Examples produced by the students from the same image resource as Figure 4 showing the quality and diversity of form and design detailing

The students were then shown how to use traditional sketching methods to develop the largely 2D representations by using elevations, sketching planes, crating, cross-sections, and projected geometry to describe the form in three dimensions (Storer & Campbell, 2012). The authors made a conscious decision not to use 2D sketching software such as Sketchbook Pro for the sketching element of this study to allow a clearer focus on the mash-up approach prior to sketching. The sketching was used to refine and blend the "borrowed" elements and details more effectively into their unique refined designs. The students were encouraged to use the mash-ups to initiate a wide variety of possible design directions; however, the more traditional method of sketching was still encouraged to add clarity and coherency to the concepts, or where the source material didn't lend itself to the intended product view.

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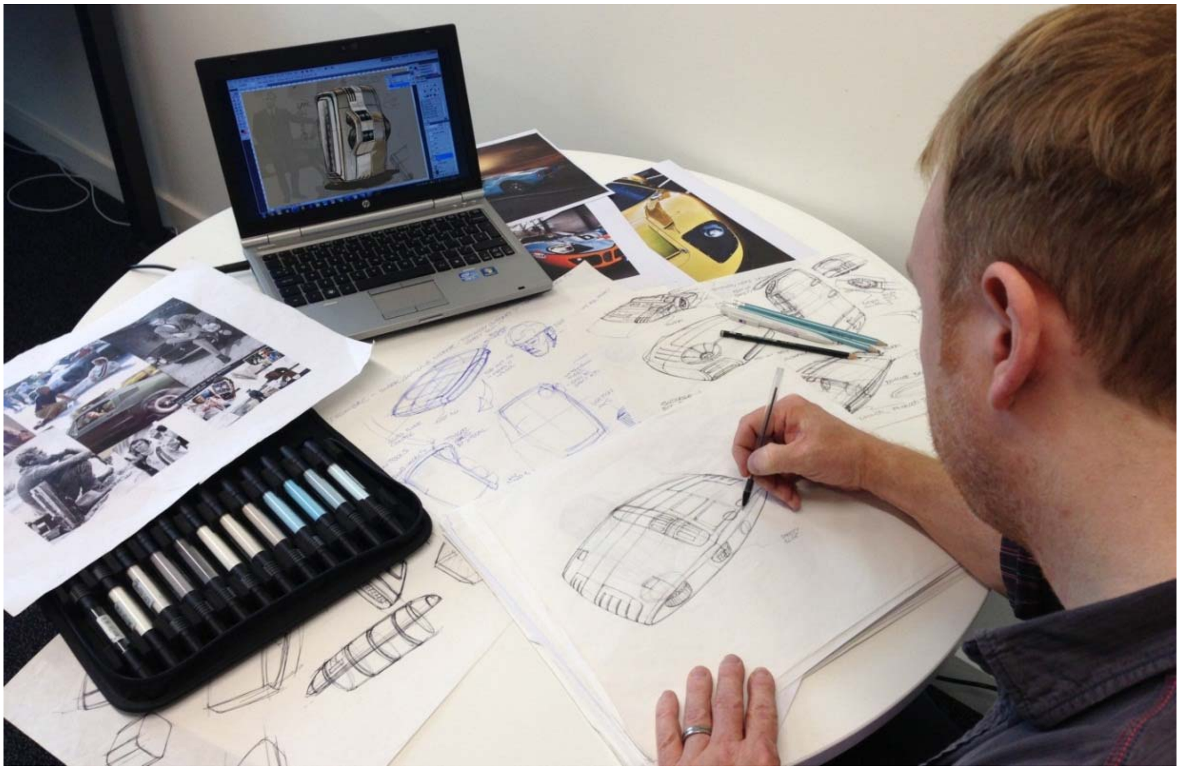

Figure 6. Using image resources and a 2D "mashed aesthetic" visualization to aid sketched development of 3D form and design detailing.

Results

The expected outcome was that students would be able to engage with the front end of the ideation process more quickly and effectively. Producing visual conceptual ideas that contained a level of form, texture and use of colour that was of a higher standard than had previously been possible through sketching alone. In order to assess the effectiveness of the approach, the authors inspected the 2D mash-ups and sketched development concepts of all the students to identify the advantages of the process when compared to more traditional sketch ideation methods.

The entire cohort of the students had engaged fully with the use of 2D mash-ups as their initial starting point, with 21 of the 29 students producing three or more substantially different design directions for their communication device. The authors noted that, drawing on their combined 28 years of experience of teaching industrial

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design sketching and visualization, that the entire cohort had made significant progress in the project in a substantially truncated timeframe when compared to traditional sketching alone. The level of design detail, subtlety of form and product semantics had also made the leap that the authors had hoped for.

Figure 7. Example of an industrial design master's student's design development using the mashed aesthetics process showing clear links to visual resource material

Further to this, the authors found that 23 of the 29 students had used the combination of 2D mash-ups and hand sketching in the way that the authors had envisaged and used the source images to "clothe" sketches in the intended materials. However, mash-ups were used more to support the sketching process rather than replacing it. Designs were still developed on paper, particularly with consideration to how the forms provided by the mash-up would work effectively in three dimensions, with the students then using CAD systems such as Solidworks to combine and refine their sketches and mash-ups into design development 3D models that could be taken to a presentation stage. For example, Figure 7 shows one student's successful combination of the methods previously cited, with initial resource material being combined effectively into a design direction mash-up which was subsequently refined through traditional sketching techniques with impressive visual fluidity from resource material through to final concept.

Discussion and Conclusions

This study offers some opinions on a novel way to approach the initial ideation phase of an industrial design project. It is clear that the use of mashed aesthetics offers the opportunity for students to create high quality ideation concepts early on in the design process by removing some barriers to creativity which stem from a lack of sketching ability.

It is also clear that students can create initial ideas more quickly, with a greater understanding and subtlety to their application of form and product semantics, not only by using forms that already have inherent beauty, complexity or historical and emotional significance, but also in that the sourcing of images is now enhanced by applications such as Pinterest, because design students can access image libraries created by professional designers who collectively have countless years of experience that shapes and informs the selection of this raw visual research resource. The process of forced interaction with the source material reduces some of the issues highlighted by McDonnagh (2004), although there can be a little too much, "borrowing" from existing designs and not enough original intellectual property generation. Nevertheless, as a means of getting started, immersion in the appropriate stylistic genres and overcoming the fear of the blank page this approach appears successful.

Industrial designers' sketching behaviour is dramatically different from that of other disciplines (Lau, Oehlberg, & Agogino, 2009), and therefore it should come as no surprise that their use and application of image manipulation software can, and arguably should differ to that of other disciplines. Industrial designers are innovators by their very nature, therefore how they use software should be open to innovation and reinterpretation. However it is the authors' and a more widely held view that sketching should always play an accompanying role in this.

The methods discussed in this paper not only have the potential to aid fast and coherent ideation for industrial designers, but also these methods could be used to aid communication between disciplines if taught to brand managers and marketing professions, feeding the co-creation process. The authors intend to experiment with teaching these techniques to students from the engineering and business schools to

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explore the potential for widening participation in design thinking activity in new product development.

This study will be followed-up by the examination of the use of hand drawn sketching within CAD systems by industrial design master's students as drivers for 3D surface creation, to ascertain what advantages there are in blurring the disconnect that exists between hand drawn sketching and 3D CAD modelling further down the design process.

References

Anderson, C. (2012). *Makers: The new Industrial Revolution*. London, United Kingdom: Random House Business Publishing.

Brown, T. (2009). *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*. New York: Harper Collins.

Cai, H., Do, E., & Zimring, C. (2009). Extended linkography and distance graph in design evaluation: an empirical study of the dual effects of inspiration sources in creative design. *Design Studies*, *31*(2),146-168.

Casden, A. (2014). Connecting: Makers, Connecting Series Short Films. [28th October 2014]. Microsoft Design Studio/Bassett & Partners. Retrieved from http://www.connectingthefilm.com

Cheng, P., Mugge, R., & Schoormans, J. (2014). A new strategy to reduce design fixation: Presenting partial photographs to designers. *Design Studies*. *35*(4), 374-391.

Crilly, N., Moultrie, J., & Clarkson, P.J. (2009) Shaping things: Intended consumer response and the other determinants of product form. *Design Studies*, *30*(3), 224-254.

Cross, N. (2011). *Design Thinking: Understanding How Designers Think and Work*. Oxford, United Kingdom: Berg Publishers.

Dreyfus, H. L., & Dreyfus, S, E. (1986) *Mind over Machine: the power of human intuition and expertise in the age of the computer.* Oxford, United Kingdom: Basil Blackwell Publishing. DOI: 10.1016/0377-2217(88)90183-X.

Goldschmidt, G., & Sever, A. (2010). Inspiring design ideas with texts. *Design Studies*, 32(2), 139-155.

Govers, P. C. M., Hekkert, P., & Schoormans, J. P. L. (2004). Happy, cute and tough: can designers create a product personality that consumers understand? in D. McDonagh, P. Hekkert, J. VanErp and D. Gyi (eds*.) Design and emotion, the experience of everyday things* (pp. 2002-2003). London, UK: Taylor & Francis.

Hurn, K. (2011). Moving Target: What are the key elements that are conducive to a creative environment for Industrial/Product Design study today*? Proceedings of the IASDR 4th World Conference on Design Research*, Delft, the Netherlands.

Hurn, K. (2013). The impact of collaborative 'live' industrial partner projects in product design higher education. *Proceedings of the 5th International Congress of the International Association of Societies of Design Research (IASDR): Consilience and Innovation in Design*, Tokyo, Japan, 26-30 August 2013, 10pp.

Industrial Design Society of America. (2014). What is Industrial Design? [20 September 2014]. IDSA, Herndon, VA, United States. Retrieved from http://www.idsa.org/education/what-is-industrial-design.

Joore, J. P. (2010). New to Improve-The Mutual Influence between New Products and Societal Change Process (Doctoral dissertation, Delft University of Technology, Netherlands). doi:10.4233/uuid:447d8e32-25f5-4d16-b1dd-f11cc245829c.

Kaleidoscope. (2009), Wanderlust – Trends in Furniture and Housewares. [16 September 2014], Kaleidoscope Inc. Cincinnati, United States. Retrieved from http://www.kascope.com/wanderlust-furniture-2011/.

Kaleidoscope. (2010), Wanderlust – Mash to the Future. [25 September 2014], Kaleidoscope Inc. Cincinnati, United States. Retrieved from http://www.kascope.com/microscope-robots-in-retro/.

Lau, K., Oehlberg, L., & Agogino, A. (2009), Sketching in Design Journals: An Analysis of Visual Representations in the Product Design Process. *Engineering Design Graphics Journal*. *73*(3).

Lawson, B. (1990). *How Designers Think: The Design Process Demystified*. Oxford, United Kingdom: Butterworth-Heinemann Publishing.

Lawson, R., & Storer, I. J. (2008). 'Styling-in' semantics. *Proceedings of Design and semantics of form and movement Conference (DeSForM)*, University of Northumbria, England, 6-7 November 2008, pp. 41-49.

McCardle, J., Storer, I. J., Torrens, G., Whitehead, S., Mailley, J., & Farrell, G. (2011). Offending Users: Designing-in Deterrence with Mobile Telephones. *The Design Journal*. *14*(3).

McDonagh, D., & Storer, I. J., (2004). Mood Boards as a Design Catalyst and Resource: Researching an Under-Researched Area. *The Design Journal*. *7*(3) 16-31.

Oxford Dictionaries (2014). *Oxford English Dictionary*. United Kingdom: Oxford University Press.

Robertson, S. (2012). Improving your visual library. Scott Robertson YouTube Channel. [11 September 2013]. YouTube. Retrieved from https://www.youtube.com/watch?v=5T8DH2miUlU

Storer, I. J., & Campbell, R.I. (2012). Using the Continuum of Design Modelling Techniques to Aid the Development of CAD Modelling Skills in First Year Industrial Design Students. *Engineering Design Graphics Journal*. *76*(3).

Storer, I. J. (2008). Reflecting on Professional Practice: Capturing an Industrial Designer's Expertise to Support the Development of the Sketching Capabilities of Novices. *Design & Technology Education: An International Journal*, 10(1), 54-72. ISSN: 1360-1431.

Tonkinwise, C. (2011). A Taste for Practices: Unrepressing style in design thinking. *Design Studies*, *32*(6) 515-610.

Winnan, C. (2013). 3D Printing: The Next Technology Gold Rush – Future Factories and How to Capitalize on Distributed Manufacturing. CreateSpace Independent Publishing Platform.

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High School Graphics Experience Influencing the Self-Efficacy of First-Year Engineering Students in an Introductory Engineering Graphics Course

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Abstract

Today's students enter engineering colleges with different technical backgrounds and prior graphics experience. This may due to their high school of provenience, which can be technical or non-technical. The prior experience affects students' ability in learning and hence their motivation and self-efficacy beliefs. This study intended to evaluate the role of prior high school graphics experience in first-year engineering students' self-efficacy beliefs in an introductory engineering graphics course. It also intended to evaluate the relationship between such freshmen's self-efficacy beliefs and their performance. Two assessment instruments were used in this study. The first is the eight-item Course Interest Survey (CIS) Confidence subscale, which was used to assess self-efficacy beliefs. The second is a multiple choice questionnaire designed on the course topics, which was used to assess performance. Ninety-nine students of the University of Brescia (Italy) participated in the experiment. Significant differences in self-efficacy were found between engineering freshmen from the technical high school versus engineering freshmen from the non-technical high school. A significant relationship between self-efficacy and performance was found only for engineering freshmen from the technical high school.

Introduction

To understand what motivates students to learn is fundamental to develop pedagogical strategies to promote student success. The effort, persistence and resilience of students through the process of learning are determined by their motivation, and particularly by their self-efficacy beliefs and expectancy for success (Pajares, 1996). Self-efficacy beliefs are also considered by many researchers as strong predictors of the level of achievement that individuals finally get (Bandura, 1997; Pajares, 1996). Therefore, many studies have tried to understand which motivational and self-beliefs provide the greater explanation and prediction of students' behavior and performance (Bong and Skaalvik, 2003; Pajares, 1996).

In engineering graphics education, previous researches conducted by Ernst and Clark have failed to find significant relationships between motivation to learn and performance or attitude in introductory engineering graphics courses. They also found no significant differences between attitudes and motivation of students at-risk and not at-risk (Ernst and Clark, 2012a; Ernst and Clark, 2012b; Clark and Ernst, 2012). In all these studies, attitude is measured in terms of spatial acuity, mental rotation abilities and 3D visualization abilities with a plurality of assessment instruments, such as the Purdue Spatial Visualization Test-Visualization of Rotations (PSVT); the Mental-Rotations Test (MRT); the VARK Questionnaire; and the North Carolina Learning Attitudes about Graphics Education Survey (NCLAGES). On the other hand, motivation is measured by using only the Motivated Strategies for Learning Questionnaire (MSLQ). Particularly, the motivational aspects of learning are measured by using the subscale MSLQ Self-efficacy Learning Performance (see an example in Clark, Ernst and Scales, 2009). The MSLQ is one of the most used self-report questionnaires to assess motivational beliefs and self-regulated learning. However, further robust self-assessment questionnaires have been developed to measure the motivational component of learning (see Bixler, 2006 for a review).

One example of such self-assessment questionnaires is the Course Interest Survey (CIS), which is a situational measure of students' motivation to learn. The Course Interest Survey was developed by Keller (2006) in correspondence to his ARCS Model of Motivational Design. The ARCS is a model aimed to select instructional strategies to generate interest and motivation in learners while connecting to instructional goals. According to such model, there are four steps for promoting and sustaining motivation in the learning process: Attention, Relevance, Confidence, and Satisfaction (ARCS) (Keller, 1987). Particularly, Confidence is described as the "expectancy for success", with particular reference to the attribution of responsibility. Learners can believe to be the makers of their learning success and attribute success to effort, or they can attribute success to learning environment, to luck, or to the difficulty of the tasks to do (Bixler, 2006; Pajares, 1996).

Table 1 shows a comparison between the items of the CIS Confidence items and the MSLQ Self Efficacy Learning Performance. Most of the items of the CIS Confidence scale are similar, but different in wording, to the items of the MSLQ Self-efficacy Learning Performance. However, there are two significant differences. Firstly, the CIS Confidence survey involves positively and negatively keyed items, whereas the MSLQ Self-efficacy Learning Performance involves only positively keyed items. This difference is important because a balance of positively and negatively keyed items is acknowledged to reduce the possibility of acquiescence bias in the responses.

Secondly, the CIS Confidence items pose the attention on the learner along with the learning environment and perception of tasks difficulty. On the other hand, MSLQ Self-efficacy Learning Performance items are narrowed on the learner as the only maker of their learning success. These differences induced us to consider the CIS Confidence survey more fit for the purpose of this study.

The perception of tasks difficulty and learning environment are particularly important for the development of the self-beliefs of students who are not familiar with some tasks. In fact, a sense of academic self-efficacy is most heavily affected by one's previous encounters with the same or similar tasks (Bandura, 1994; Bong and Skaalvik, 2003; Pajares, 1996). Students who are familiar with the skills required to accomplish a task can interpret their prior achievements and identify the skills on which to develop their self-efficacy beliefs. These self-efficacy beliefs are goal-referenced evaluations and can be a good predictor of their performance (Pajares, 1996). On the other hand, students

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Table 1 – MSLQ Self-Efficacy Learning Performance versus Course Interest Survey Confidence

MSLQ Self-Efficacy Learning Performance items	CIS Confidence items*
I believe I will receive an excellent grade in this course	You have to be lucky to get good grades in this course.
I'm certain I can understand the most difficult material presented in the reading for this course	I find the challenge level in this course to be about right: neither too easy not too hard.
I'm confident I can learn the basic concepts taught in this course	As I am taking this class, I believe that I can succeed if I try hard enough.
I'm confident I can understand the most complex material presented by the instructor in this course	The subject matter of this course is just too difficult for me.
I'm confident I can do an excellent job on the assignments and tests in this course	It is difficult to predict what grade the instructor will give my assignments.
I expect to do well in this course	I feel confident that I will do well in this course.
I am certain I can master the skills being taught in this course	Whether or not I succeed in this course is up to me.
Considering the difficulty of this course, the teacher and my skills, I think I will do well in this class	I get enough feedback to know how well I am doing.

Note: * = items are here ordered to highlight the similarity with MSLQ items. See Table 3 for their real order

who are not familiar with the tasks required to successfully perform need to rely on vicarious experience on the basis of similar others' performance on the tasks and on evaluative feedback (Bong and Skaalvik, 2003). Such students' self-beliefs are usually affected by social comparison or relativistic impression. Therefore, they cannot be a predictor of their performance as good as for their 'expert' peers. Fantz, Siller and DeMiranda (2011) found that pre-collegiate technical experiences produce a significant difference in self-efficacy related to engineering studies between students who had experience versus those who did not. In particular, students with a pre-collegiate experience in technology education classes at the high school level had significantly higher self-efficacy scores.

First-year engineering students unfamiliar with engineering graphics generally come from non-technical high schools and are without prior graphics experience (Metraglia, Baronio and Villa, 2011). In a study we conducted in 2013 on the students of an introductory engineering graphics course, we found that the impact of pre-collegiate technical experiences seems to persist on self-efficacy beliefs even at the end of the course (Metraglia, Baronio, Villa and Adamini, 2013). In that experiment, we developed a self-assessment questionnaire composed of statements on well-defined tasks related to the course topics, such as "I can understand the indications of threaded parts in a drawing" or "I know how to insert the right dimensional tolerance, once the type of coupling is noted". The self-assessment questionnaire was administered to students at the end of the course and before the exam. It was found that first-year engineering students who came from technical high schools were significantly more confident than

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students who came from non-technical high schools, in almost all the tasks. The result of that study poses the possibility of a long-term impact of the high school of provenience and initial familiarity with engineering graphics on students' self-efficacy beliefs.

The present study therefore sets out to examine the role of the high school of provenience in shaping the self-efficacy and expectancy beliefs of first-year engineering students in an introductory engineering graphics course. This study also attempted to find relationships between self-efficacy and expectancy beliefs and performance. On the basis of previous research it was predicted that:

1. Introductory engineering graphics students from technical high schools have a higher level score of self-efficacy compared to students from non-technical schools;
2. For students from high technical schools, self-efficacy beliefs and performance are positively correlated;
3. For students from non-technical high schools, self-efficacy beliefs and performance are not correlated.

Methodology

Population and participants

The course "Disegno Tecnico Industriale" (namely 'Technical Drawing', but usually translated as 'Basics of Technical Drawing' or 'Basics of Engineering Drawing/Graphics') is an introductory course designed to teach the fundamentals of engineering/technical graphics. The course is listed on the University of Brescia's requirements for the Bachelor's degree in Mechanical Engineering, Automation Engineering and Management Engineering, and it is directed to first-year students. A total of 99 students voluntarily participated in the study. The population for this study was the 180 students enrolled for the first time in the course "Basics of Engineering Drawing" in the spring semester, 2012. Therefore, the response rate was about 55%. The majority of students were Italian (81.8%), male (75.8%), between the ages of 19 and 20 (86.8%), and from non-technical high schools (81.8%). The demographic characteristics of the sample are shown in Table 2.

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Table 2 – Demographics of the Study's sample

Demographic	Category	n	Percent
Sex	Male	75	75.8%
	Female	24	24.2%
Country of origin	Italy	81	81.8%
	Prefer not to respond	10	10.1%
	Morocco	3	3.0%
	Cameroon	2	2.0%
	Romania	2	2.0%
	Lebanon	1	1.0%
Age	19	1	1.0%
	20	63	63.6%
	21	23	23.2%
	22	11	11.1%
	27	1	1.0%
Engineering Major	Mechanical	47	47.5%
	Management	40	40.4%
	Industrial Automation	12	12.1%
High School of provenience	Technical	18	18.2%
	Non-Technical	81	81.8%

Instrumentation: Motivation

The Course Interest Survey (CIS) was used to measure students' self-efficacy beliefs. Two authors of this paper had already used the CIS in previous research on motivation in engineering graphics education, particularly on the use of web comics to motivate weaker students in introductory engineering graphics courses (Metraglia and Villa, 2014). The CIS is a 34-item instrument measuring four different scales – attention, relevance, confidence and satisfaction – which can be used by researchers as a whole or independently. Each item is a statement with a five-point Likert-type scale used to determine how true each statement is for each student. The rating scale is uni-polar, i.e. it reflects a single construct running from low to high, and it is composed by five labeled points with the most negative point first: 'Not True', 'Slightly True', 'Moderately True', 'Mostly True', and 'Very True'. This rating scale agrees with the recommendations of Krosnick and Fabrigar (1997) on the development of uni-polar scales to measure a single construct. For this study, the eight items of to the CIS Confidence scale were used (see Table 3). The original statements of the CIS were translated into Italian. Each statement had five points ranging from 'Not True' to 'Very True'. The statements were scored with a +1 for Not True, +2 for Slightly True, +3 for Moderately True, +4 for Mostly True, and +5 for Very True. For each respondent, the total CIS Confidence score was divided by eight (the number of items). This converts the totals into a score ranging from 1 to 5. Please note the items 2, 4 and 5 in Table 3 are negatively keyed items. The responses have to be reversed before they can be added into the response total. That is, for these items, 5 = 1, 4 = 2, 3 = 3, 2 = 4, and 1 = 5 (Keller, 2006).

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The validity of the CIS as a situation specific measure of motivation has already been demonstrated in the work of Keller (2006), in which Cronbach's alpha was used to measure the internal consistency of the responses for the instrument. For the CIS Confidence subscale, the original study of Keller (2006) had a Cronbach's alpha = 0.81. Our previous research on web comics in engineering graphics education had a Cronbach's alpha = 0.77 (Metraglia and Villa, 2014). For this study, a value of 0.70 for Cronbach's alpha was considered acceptable (Field, 2009). The instrument used in this study resulted in a Cronbach's alpha = 0.76.

Instrumentation: Performance

The second instrument was a multiple choice questionnaire designed by the researchers to assess the skills of students at the end of the course "Basics of Engineering Drawing". Such questionnaire has not officially been validated yet, but preliminary analysis showed it may be considered valid and reliable. We had a positive feedback by five students enrolled in the course who were asked to judge the clarity and the consistency of the questions. We also found a high level of test-retest reliability (r = 0.82) in a pilot study, in which we administered the questionnaire to a sample of 15 engineering freshmen enrolled in the course in two separate occasions distant two days. This multiple choice questionnaire has been used for two years in the course "Basics of Engineering Drawing" at the University of Brescia to evaluate students' comprehension of the course. The course topics are: projections methods; representation and orthographic views; cuts and sections; dimensioning; parts and assemblies; taking dimensions from physical mock-ups; tolerances; threading; fasteners; and unthreaded elements of machines. The questionnaire was administered via computer in a laboratory. The questions were randomly selected from panels of questions in correspondence with the course topics. The total amount of questions in the panels was 300. The questionnaire was made by 18 questions, each with five possible answers of which only one was correct. The order of the possible answers was random for each administered questionnaire. The scores were +1 for each right answer, 0 for no response, and -0.25 for each wrong answer. For each respondent, the total score was then converted to tenths.

Procedure

Students were taught over 13 weeks and were asked to complete the CIS Confidence survey during the last week of class, thereby allowing them to benefit from the whole course prior to completing the survey. The multiple choice test to measure Performance was administered one week after the end of the completion of the course (two weeks after the CIS Confidence survey).

Results

Table 3 lists the CIS Confidence statements statistics for the group of students from technical high schools (T) and the group of students from non-technical high schools (NT). Descriptive statistics were used to find the skewness and kurtosis of the variables to determine normality of the data and residual plots, and scatter-plots for each variable were performed and visually inspected for any violations. The data of the total scores of Confidence scale and Performance in technical high school and non-technical high school groups were found to be within appropriate limits for the assumptions of the general linear model and adequate for this study.

Table 3 – Means and percentages for CIS Confidence statements

Statement	High School*	M	Not True	Slightly True	Moderately True	Mostly True	Very True
1. I'm confident I will do well in this course	T	3.72	0%	11%	28%	39%	22%
	NT	3.30	5%	16%	38%	26%	15%
2. You have to be lucky to get good grades in this course	T	1.67	44%	44%	11%	0%	0%
	NT	2.04	31%	43%	20%	4%	3%
3. Whether or not I succeed in this course is up to me.	T	4.28	0%	0%	11%	50%	39%
	NT	4.04	1%	6%	20%	33%	39%
4. The subject matter of this course is just too difficult for me	T	1.28	72%	28%	0%	0%	0%
	NT	1.88	32%	52%	12%	4%	0%
5. It is difficult to predict what grade the instructor will give my assignments.	T	3.06	6%	17%	44%	33%	0%
	NT	3.17	3%	20%	43%	27%	7%
6. Since the start of the course, I've been confident that I would have been able to succeed if I tried hard enough	T	4.11	0%	0%	17%	56%	28%
	NT	3.38	1%	19%	37%	27%	16%
7. I find the challenge level in this course to be about right: neither too easy nor too hard.	T	3.61	6%	6%	33%	33%	22%
	NT	3.44	1%	16%	35%	33%	15%
8. I get enough feedback to know how well I am doing.	T	3.11	6%	17%	44%	28%	6%
	NT	2.84	3%	37%	37%	21%	3%

Note: * T = Technical High School; NT = Non-Technical High School

An independent samples t-test was performed to compare the CIS Confidence scores (see Table 4) and the Performance scores (see Table 5) of the group of engineering students from technical high schools versus the group of engineering students from non-technical high schools. The average CIS Confidence score of engineering students from technical high schools was significantly higher than the average CIS Confidence score of engineering students from non-technical high schools (mean difference = 0.36, *t* = 2.54, *p* = .01).

The Performance scores were not significantly different between the two groups (mean difference = 0.04, *t* = 0.10, *p* = .92). There was a significant correlation between the CIS Confidence score of engineering freshmen from technical schools and their performance (*r* = .68, *p* = .02), whereas there was not a significant correlation between the CIS Confidence score of engineering freshmen from non-technical schools and their performance (*r* = -.09, *p* = .92). Table 6 shows that considering all the participants, with no regard to the high school of provenience, there was not a significant correlation between the CIS Confidence score and the Performance score (*r* = .10, *p* = .31).

Table 4 – T-test CIS Confidence Technical High School/Non-Technical High School

Group	n	M	SD	Mean Difference	*t*	*df*	*p*
Technical High School	18	3.85	0.56	0.36	2.54	97	0.013
Non-Technical High School	81	3.49	0.55				

Table 5 – T-test Performance test Technical High School/Non-Technical High School

Group	n	M	SD	Mean Difference	*t*	*df*	*p*
Technical High School	18	7.69	1.50	0.04	0.10	97	0.92
Non-Technical High School	81	7.73	1.33				

Table 6 – Correlation matrix CIS Confidence and Performance Technical High School/Non-Technical High School

Group	n		CIS	Performance
Technical High School	18	**CIS**	-	.68 (*p* = .02)
		Performance	.68 (*p* = .02)	-
Non-technical high school	81	**CIS**	-	-.09 (*p* = .43)
		Performance	-.09 (*p* = .43)	-
Total of participants	99	**CIS**	-	.10 (*p* = .31)
		Performance	.10 (*p* = .31)	-

The responses to the single items were found to be not significantly distributed in both groups. This is in good agreement with Keller (2006), who argues that, being the survey a situation specific measure, there is no expectation of a normal distribution of responses. Mann-Whitney tests were conducted to test the differences between the two groups on the eight items of the survey. Table 7 reports Mann-Whitney test values (*U*), level of significance (*p*) and effect size (*r*) for the differences between the two groups for each item. Effect sizes provide a standardized measure of the size of the effects observed and determine the strength of the relationship between variables. Criteria to indicate effect sizes are *r* = .01 (small effect), *r* = .03 (medium effect), and *r* = .05 (large effect). The effect size r was calculated by converting the U test statistics into a z-score and by dividing such z-score by the square root of the number of the total observations (Field, 2009), i.e. 99 (18 technical high school students + 81 non-technical high school students).

Table 7 shows that there is a significant difference between the responses of engineering students from technical high schools and engineering students from non-technical high schools to two items: “The subject matter of this course is just too difficult for me”, *U* = 404.00, *z* = -3.24, *p* = .001,*r* = -.33 (a medium effect) and “Since the start of the course, I’ve been confident that I would have been able to succeed if I tried hard enough”, *U* = 422.50, *z* = -2.90, *p* = .004, *r* = -.29 (a small to medium effect).

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Table 7 – Mann-Whitney tests CIS Confidence statements
Technical High School/Non-technical high school

Statement	High School*	Median	Avg. Rank	*U*	*Z*	p	Effect Size *r*
1. I'm confident I will do well in this course	T	Mostly True	59.11	565.00	-1.55	.121	-.16
	NT	Moderately True	47.98				
2. You have to be lucky to get good grades in this course	T	Slightly True	58.50	576.00	-1.48	.138	-.15
	NT	Slightly True	48.11				
3. Whether or not I succeed in this course is up to me.	T	Mostly True	54.08	655.50	-0.71	.478	-.07
	NT	Mostly True	49.09				
4. The subject matter of this course is just too difficult for me	T	Not True	45.99	404.00	-3.24	.001	-.33
	NT	Slightly True	68.06				
5. It is difficult to predict what grade the instructor will give my assignments.	T	Moderately True	51.67	699.00	-0.29	.773	-.03
	NT	Moderately True	49.63				
6. Since the start of the course, I've been confident that I would have been able to succeed if I tried hard enough	T	Mostly True	67.03	422.50	-2.90	.004	-.29
	NT	Moderately True	46.22				
7. I find the challenge level in this course to be about right: neither too easy nor too hard.	T	Mostly True	54.44	649.00	-0.76	.448	-.08
	NT	Moderately True	49.01				
8. I get enough feedback to know how well I am doing.	T	Moderately True	57.31	597.50	-1.26	.207	-.13
	NT	Moderately True	48.38				

Note: *T = Technical High School, NT = Non-technical High School

Discussion

This study was concerned with the association between the type of high school of provenience (technical or non-technical) and self-efficacy beliefs of first-year engineering students in an introductory engineering graphics course. It was intended to evaluate the role of prior graphics experience in engineering freshmen's motivational self-beliefs and the relationship between such self-beliefs and freshmen's performance.

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Most of the studies conducted so far in introductory engineering graphics courses have used the Motivated Strategies Learning Questionnaire (MSLQ) to assess motivational beliefs. In this study, self-efficacy beliefs were measured by using the Course Interest Survey (CIS), particularly the CIS Confidence survey. The aim of using the CIS Confidence survey was to better understand the effect of learning environment and perception of difficulties on the shaping of self-beliefs. Three hypotheses were stated in the above Introduction.

The first hypothesis was confirmed by the results: first-year engineering students from technical high schools scored significantly higher levels of self-efficacy compared to their peers from non-technical high schools. This result supports our previous study on self-assessment on well-defined tasks (Metraglia et al., 2013), in which we found that at the end of an introductory engineering graphics course, engineering freshmen from technical high schools are more confident in being able to solve basic graphics tasks, if compared to their peers coming from non-technical high schools. This result is also in line with the study of Fantz et al. (2011), who found that students with a pre-collegiate experience in technology education classes at the high school level have significantly higher self-efficacy scores related to engineering studies compared to students without such kind of experience. In our experiment, two statements played the major role in defining the difference between the self-efficacy of students from the technical high school and engineering students from the non-technical high school. The first refers to the perception of difficulty: “The subject matter of this course is just too difficult for me”. The second refers to the self-perception of initial familiarity: “Since the start of the course, I’ve been confident that I would have been able to succeed if I tried hard enough”. Note that such two statements are typical of the CIS Confidence pool of items, whereas a counterpart does not exist in the MSLQ Self-efficacy Learning scale. This supports the need to use different assessment instruments to assess motivational beliefs to get a better overview of what motivates students to learn engineering graphics, as also argued by Clark and Ernst (2012). We conclude that first-year engineering students without prior technical and graphics experience are aware of their difficulties in learning the fundamentals of engineering graphics. We also conclude that this awareness has a significant impact on developing their self-efficacy beliefs. This is in good agreement with Delahunty et al. (2013), McCadle (2002), Metraglia et al. (2011) and Pajares (1996).

The second hypothesis was confirmed by the results: for first-year engineering students from technical high schools, self-efficacy beliefs and performance were positively correlated. This is in agreement with Bandura (1994), Bong and Skaalvik (2003) and Pajares (1996). In fact, first-year engineering students from the technical high school have already some experience and familiarity with engineering graphics tasks, since they previously encountered the basics of engineering graphics at their high school. They can hence better interpret which skills are associated with the required

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performance, and evaluate their preparation. Their self-efficacy beliefs are based on previous experience, and can hence maximize the prediction of their performance.

The third hypothesis was confirmed by the results: for first-year engineering students from non-technical high schools, self-efficacy and expectancy beliefs and performance were not correlated. This is in coherence with Bong and Skaalvik (2003), who argued that the lack of experience at the very initial stage of education is expected to exhibit variability just because it is hard for students to formulate self-efficacy beliefs without prior experience on topics.

This study indicated that a better understanding of the background of first-year engineering students is important to the understanding of their self-beliefs and to the prediction of their performance. Note that if we considered the entire sample of the students of this study without distinction between the kind of high school of provenience, self-efficacy beliefs and performance would not be correlated, as also found with Ernst and Clark (2012b). The literature on self-beliefs in academic motivation (see Pajares, 1996) also indicates other factors correlated to motivation, such as gender and self-beliefs. An ongoing study on the same sample of this study is aimed to assess the relationship between the gender of students and their self-beliefs in an introductory engineering graphics course.

This study also indicated that further motivational assessment instruments need to be used to understand self-beliefs and expectancy for success of the students in engineering graphics courses. Situational measures of students' motivation to learn are especially needed to evaluate the efficacy of pedagogical methodologies used by researchers. It is hence recommended to assess the motivation of students before and after the course, to better evaluate the impact of instructional methodologies.

Three factors need to be considered in evaluating the findings of the present research. The first factor is that the engineering drawing skills of engineering freshmen at the beginning of the course were not assessed. In fact, only the high school of provenience was considered as independent variable. This is a potential source of unreliability. In fact, despite the technical high school has the major role in shaping such kind of experiences (Fantz et al, 2011), engineering freshmen from the technical high school may not all have better engineering drawing skills than the 'average' freshman. Similarly, students from the non-technical school may sometimes have some prior graphics experiences because of their personal interest, and may have hence a better background compared to their peers from non-technical schools. The second factor is that the questionnaire used to assess the performance is not validated yet. Moreover, it was designed and tailored to the topics taught at the course "Basic of Engineering Drawing" of the University of Brescia. Such topics may differ from the topics of other introductory engineering graphics courses taught in other colleges. It is hence difficult to compare the performances of the sample of students of this study with the ones of other

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studies. In a further study it would be useful to assess students' performance or attitude by using one of the validated questionnaires used, for example, in the studies conducted by Ernst and Clark. The third factor is that the populations compared in this study to others in the field do not include such majors in the USA titled automation and management engineers. Therefore, it is hard to do a direct comparison between Italian and American engineering students in relation to such majors. However, this study concerns the very beginning of the educational training. In the first year, engineering students generally learn the basics of mathematics, physics, chemistry, informatics, and, of course, engineering graphics. The curricula of the majors are hence little or none distinct at this stage. Therefore, we believe that the results of this study are not affected by the kind of major engineering students are enrolled in.

In conclusion, the high school of provenience (technical or not) affects the self-efficacy beliefs of first-year engineering students in introductory engineering graphics courses. First-year engineering students from technical high schools are more confident due to their prior technical and graphics experience. Such students are good estimators of the skills required to successfully perform. For this kind of students, self-beliefs and performance are correlated. First-year engineering students from non-technical high schools are less confident due to their lack of prior graphics experience. Such students are not able to assess the skills required to successfully perform. For this kind of students, self-beliefs and performance are not correlated and it is hence more difficult to predict their performance. Apparently, the performances of first-year engineering students from non-technical high schools do not significantly differ from the ones of first-year engineering students from technical high schools. However, students from non-technical high schools need adapted motivational instruments and methodologies to raise their self-efficacy beliefs.

References

Bandura, A. (1994). Self-Efficacy. In V.S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (pp. 71–81). New York: Academic Press.

Bixler, B. (2006). Motivation and its relationship to the design of educational games. *NMC. Cleveland, Ohio.* Retrieved from: *http://hrast.pef.uni-lj.si/docs/research/Serious%20games/Motivation%20in%20Educ%20Games.pdf*

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review, 15*(1), 1–40.

Clark, A. C., & Ernst, J. V. (2012). A learner profile thematic review of introductory engineering design graphics students. *Proceedings of the Engineering Design Graphics Division of the American Society of Engineering Education's 67th Mid-Year Conference, Limerick Ireland, Session* (pp. 106–110).

ISSN: 1949-9167

Clark, A. C., Ernst, J. V., & Scales, A. Y. (2009). Results of a study using the Motivation Strategies for Learning Questionnaire (MSLQ) in an introductory engineering graphics course. In *Annual meeting of the American Society for Engineering Education Southeast Section Conference, Austin, TX.*

Delahunty, T., Seery, N., Lynch, R., & Lane, D. (2013). Investigating student teachers' approach to solving applied analytical graphical problems. *Engineering Design Graphics Journal, 77*(1), 5–22.

Ernst, J. V., & Clark, A. C. (2012a). At-risk visual performance and motivation in introductory engineering design graphics. In *American Society for Engineering Education*. American Society for Engineering Education.

Ernst, J. V., & Clark, A. C. (2012b). Attitudes and Motivation of Students in an Introductory Technical Graphics Course: A Meta-analysis Study. *Engineering Graphics Design Journal, 76*(2), 1–16.

Fantz, T. D., Siller, T. J., & DeMiranda, M. A. (2011). Pre-Collegiate Factors Influencing the Self-Efficacy of Engineering Students. *Journal of Engineering Education, 100*(3), 604–623.

Field, A. P. (2009). *Discovering statistics using SPSS* (3rd ed). *Introducing Statistical Methods Series*. Los Angeles, [Calif.], London: SAGE.

Keller, J. M. (1987). Development and use of the ARCS model of motivational design. *Journal of Instructional Development, 10*(3), 2–10.

Keller, J. M. (2006). *Development of two measures of learner motivation*. Tallahassee, Florida: Instructional Systems Program. Retrieved from http://olpcorps.wikispaces.com/file/view/ARCSMEA+Partial+Draft+060222.doc

Krosnick, J. A., & Fabrigar, L. R. (1997). Designing Rating Scales for Effective Measurement in Surveys. In L. Lyberg, P. Biemer, M. Collins, E. de Leeuw, C. Dippo, N. Schwarz, & D. Trewin (Eds.), *Survey Measurement and Process Quality* (pp. 141–164). Hoboken, NJ, USA: John Wiley & Sons, Inc.

McCardle, J. R. (2002). Back to the Drawing Board? *Journal of Design and Technology Education, 7*(2), 123–132.

Metraglia, R., Baronio, G. and Villa, V. (2011). Learning Levels in Technical Drawing Education: Proposal for an Assessment Grid based on the European Qualifications Framework (EQF). In Culley, S.J.; Hicks, B.J.; McAloone, T.C.; Howard, T.J.; Ion, B. (eds) *Proceedings of the 18th International Conference on Engineering Design (ICED 11), Impacting Society through Engineering Design, Vol. 8: Design Education, August 15-19, 2011 Lingby/Copenaghen, Denmark*. Glasgow: The Design Society, pp. 161-172.

Metraglia, R., Baronio, G., Villa, V. and Adamini, R. (2013) Development of a self-assessment questionnaire for basic technical drawing skills: a preliminary study. *Procedia - Social and Behavioral Sciences, 106*, 848–859.

ISSN: 1949-9167

Metraglia, R. and Villa, V. (2014). Engineering Graphics Education: Webcomics as a Tool to Improve Weaker Students' Motivation. *Research Journal of Applied Sciences, Engineering and Technology, 7*(19), 4106–4114.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*(4), 543–578.

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