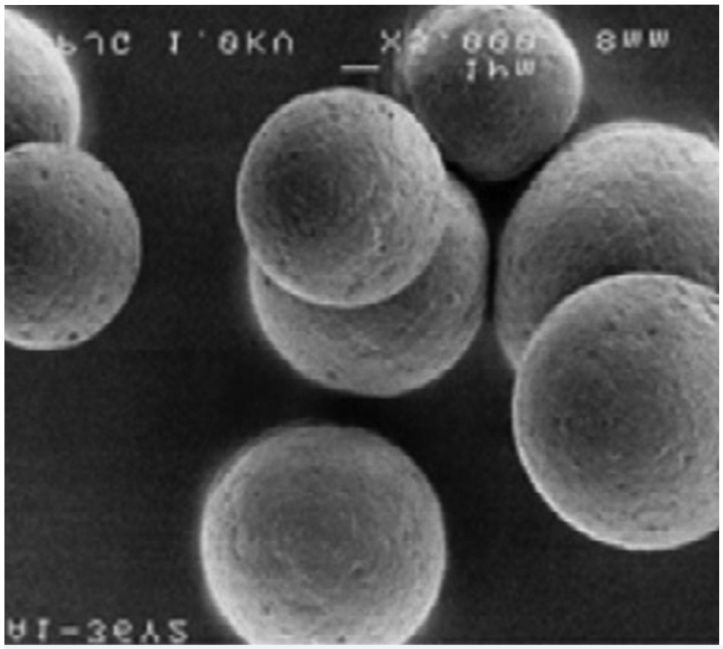
ISSN 2217-379X

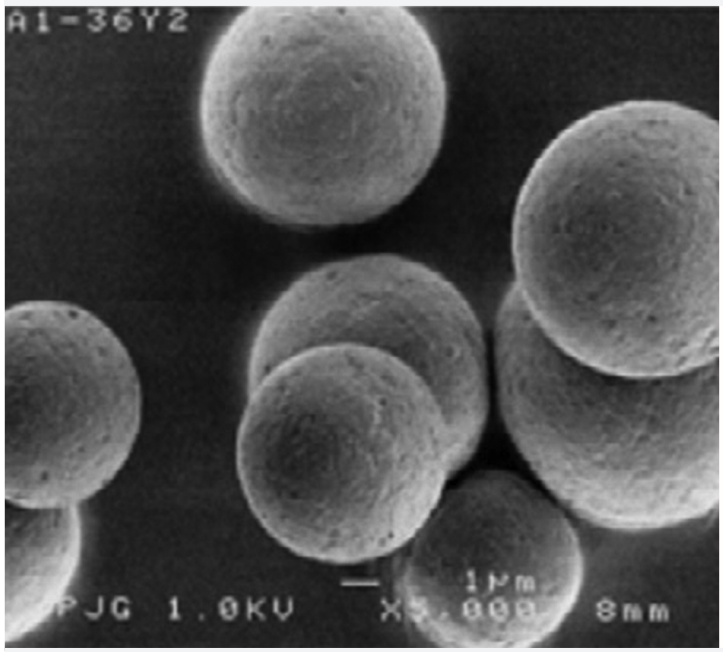
University of Novi Sad
Faculty of Technical Sciences
DEPARTMENT OF GRAPHIC
ENGINEERING AND DESIGN

Volume **12**
Number **3**
September **2021**

JGED

JOURNAL OF GRAPHIC ENGINEERING AND DESIGN





JGED

JOURNAL OF GRAPHIC ENGINEERING AND DESIGN

3/2021

Volume 12, Number 3, September 2021.

Published by

UNIVERSITY OF NOVI SAD, SERBIA
Faculty of Technical Sciences
Department of Graphic Engineering and Design

PUBLISHED BY

University of Novi Sad
Faculty of Technical Sciences
DEPARTMENT OF GRAPHIC ENGINEERING AND DESIGN

Address:
Faculty of Technical Sciences,
Department of Graphic
Engineering and Design,

Trg Dositeja Obradovića 6
21000 Novi Sad, Serbia

Telephone numbers:
+381 21 485 26 20
+381 21 485 26 26
+381 21 485 26 21

Fax number:
+381 21 485 25 45

Email:
jged@uns.ac.rs

Web address:
www.grid.uns.ac.rs/jged

Frequency: 4 issues per year
Printing: Faculty of Technical Sciences, Department of Graphic Engineering and Design

Circulation: 200

Electronic version of journal available on www.grid.uns.ac.rs/jged

E-ISSN 2217-9860

The journal is abstracted/indexed in the Scopus and Directory of Open Access Journals

CIP - Katalogizacija u publikaciji
Biblioteka Matice srpske, Novi Sad
655
JGED : Journal of Graphic Engineering and Design / editor Dragoljub Novaković. - Vol. 1, No. 1 (nov. 2010) - Sciences, Department of Graphic Engineering and Design,
2010-. 30 cm
Četiri puta godišnje
ISSN 2217-379X
COBISS.SR-ID 257662727

Art Director
Uroš Nedeljković

Layout design
Bojan Banjanin

Journal cover design
Nada Miketić

JOURNAL OF GRAPHIC ENGINEERING AND DESIGN

Volume 12, Number 3, September 2021.

Contents

Original scientific paper
http://doi.org/10.24867/JGED-2021-3-005

Investigation of color values of inkjet and laserjet prints on recycled papers

ABSTRACT

The aim of this study is to compare laserjet printing and inkjet printing properties on recycled papers. In the study, we recycled reference papers prepared in accordance with the INGEDE 11p standard. After recycling the papers, we produced test papers in the laboratory environment and examined the physical and optical properties of the obtained papers. We applied calendering process at 100 °C temperature and 20 bar pressure on the obtained test papers. After this process, we printed trigromy color measurement scales with inkjet and laserjet printers on the test papers obtaine Finally, using the spectrophotometer, we determined the printing properties of both print types.
When we examined the results, we determined that in most of the printability parameters, laserjet had a superior performance and was a more usable printing system. For example, while the inkjet cyan density value is 0.94, the laserjet is 1.05. While M + Y trapping value was 28.23 in inkjet, it was 92.20 in laserjet. For example, we found the Gloss value as 2.53 in inkjet and 4.23 in laserjet. While inkjet cyan print chroma value is 44.03, it is 48.09 in laserjet. In addition, we determined that laserjet printing reached a wider area as a color gamut.
Based on the color measurement results of both printing types, we have determined that the printability of recycled papers is reasonable. We have determined with experimental results that laserjet printing produces better quality prints in a short time, especially in the office environment.

KEY WORDS
Ingede, recycling, inkjet printing, laserjet printing, cmyk

Ufuk Yilmaz [1]
Ahmet Tutuş [1]
Sinan Sönmez [2]

[1] Kahramanmaraş Sütçü Imam University Forest Industry Engineering
[2] Marmara University, Applied Sciences/Department of Printing Technologies

Corresponding author:
Ufuk Yilmaz
e-mail: kufu27@hotmail.com

First received: 27.2.2021.
Revised: 8.5.2021.
Accepted: 24.5.2021.

Introduction

In recent years, forest resources have decreased and demand for paper has increased. To meet these demands, the use of waste papers in pulp with the leadership of Japan and Western Europe has gained great importance. According to European Paper Recycling Council (2017), 72 % of the paper consumed in Europe was recycled. This rate is 71.9% in 2015.Compared to 2015, the collection of waste paper for recycling increased by 0.9% and reached 59.5 million tons. The number of countries that recycled below 60% in 2016 decreased to 9. Currently, 17 countries recycle over 70%. On average, paper fibers are recycled 3.6 times in Europe. According to Environmental Paper Network (2018) this rate is approximately 2.4 times higher than the world average. Again according to to European Paper Recycling Council (2017), the European Union is the region with the highest rate of paper recycling worldwide. While the world average is 58.6 percent with 2016 data, this rate is 72 in the European Union. In addition to the many advantages of recycling, the amount of chemi-

cals, energy and water spent on recycling waste paper to pulp is much less compared to the pulp production from wood (Çiçekler & Tutuş, 2019). Considering these data, it is possible to see that waste paper recycling is becoming more important every year. It should be noted, however, that unless we can recycle waste papers at the maximum level, we will not be fully successful. Although waste papers are a good alternative to raw materials, fiber sizes decrease after recycling. Due to the fiber length decrease, the resistance properties of the paper also decrease. As is known, the resistance properties of the paper are important factors affecting the print quality.

Paper recycling is directly connected to the printing industry. A generally preferred method for removing detached particles from the pulp is flotation (Tutak, 2015). To recycle paper, deinking has to be performed to improve the final color and overall quality of the recycled paper. Among the various de-inking methods, chemicals such as peroxides, caustic soda, and surfactants are commonly used (Mauchaufé et al., 2019). Deinking agents often include fatty acids, nonionic surfactants, or mixtures of both species, but these materials can be modified with different chemicals to achieve better results (Tutak, 2015).

The aim of this study is to compare laserjet printing and inkjet printing properties on recycled papers. The obvious advantage of laserjet printing over inkjet printing is its color gamut value, printing color value, printing gloss value, etc. (Jurič et al., 2013). A study similar to this study was carried out in the article titled Optical paper properties and their effects on color reproduction and perceived print quality. In this mentioned study, Jurič et al. (2013) used ten different types of uncoated and coated papers. It carried out a visual evaluation of the printed samples to correlate the effect of the optical properties of the paper with the printing quality under different light sources. As a result, it was determined that, unlike opacity, the whiteness and brightness of the paper were related to the print quality.

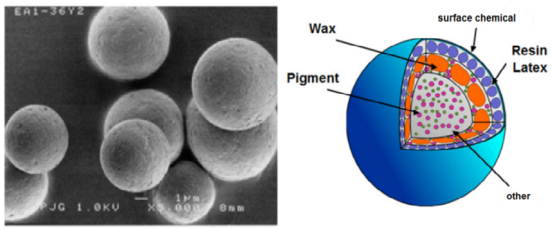
Digital printing systems

Digitalization, experienced in almost every sector on a global scale, has also affected the printing industry. With its advantages and new opportunities, it has reached the power to guide the sector. Digital printing has evolved rapidly over time and has ceased to be a replacement for traditional printing systems and has become an important part of the industry with its innovative and inspiring features (Tuncel, 2019). In recent years, many digital printing machines have been used in the printing industry. Digital printing machines have many possibilities that traditional printing systems cannot. The most important feature that makes digital printing stand out compared to other printing systems is that low-circulation jobs can be printed at a low cost. Apart from that, digital printing systems can produce variable data as well as many features such as easy updating, printing, and distribution (Romano, 2000).

Laserjet printing

The laser printer uses a large memory to print the whole page at once. The digital page view created in the memory of the printer is transferred to the drum with the help of a laser gun. Toner sticks to the parts of the drum magnetized by the laser beam. In this way, the desired characters and graphics are formed on the paper touching the drum.

Toner: It is a component consisting of dry and very small particles called “toner”, the main coloring material in copiers and laserjet printers. Depending on the production technology, the diameter of the toner grain varies between 5-10 µm. Toner is powder dyes made of carbon element. They are produced in black, red, blue and yellow colors. Toner particles, in their simplest form, contain 50% iron oxide and 50% plastic. Iron oxide allows the toner to be charged electro statically easily. On the other hand, plastic material dissolves toner particles. According to the production technology of the toner particle, there are adhesives/adhesives resin/latex, lubricant, easy dispersion counter wax and surface chemicals, and pigments (Karademir et al., 2013). The structure of the toner particle is given in Figure 1 below.



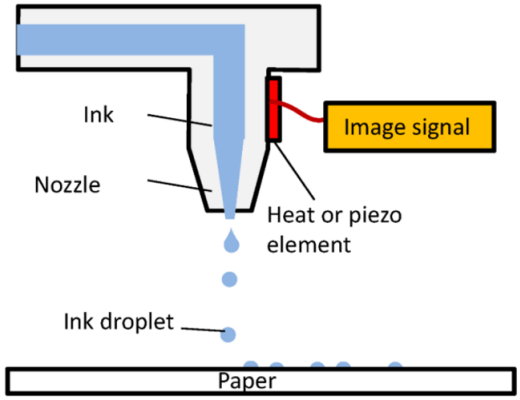
» **Figure 1:** *The structure of the toner particle (Karademir et al., 2013)*

Inkjet Printing

Inkjet printing systems are very new and developed towards the end of the 1980s for office automation applications. Requires a fundamentally different process unlike traditional methods (Karasu et al., 2019). The Inkjet printing system is applied in two ways. One is Continous Inkjet and the other is Drop-on-Demand. In Continous, ink droplets flow through the print head, while ink droplets of certain diameters are created by the applied charge process. These droplets are sent to the areas where printing is desired on paper with the charging process. In areas where printing is not required, the ink is collected in droplet holder (droplet capture) and sent back to the ink tank via a high pressure pump. Today's technology prints at 600 dpi (Hoffman, 2005). In Drop-on-Demand, ink is sprayed on paper with the help of heat. A small

heater (Heating element) is used, which suddenly heats the ink, located inside the spray mouth. With increased heat, part of the ink evaporates, and this gas bubble pushes the remaining ink forward, thus towards the paper. This is done several thousand times per second.

These types of printers print extremely small ink droplets on the paper at high speed. These droplets are usually 50 to 60 microns in diameter (a human hair is 70 microns in diameter). Structures erupting them are lined up to store 1440x720 dots per inch resolution. Below is a schematic representation of the inkjet on-demand printer in Figure 2.



» **Figure 2:** *Inkjet system (Lau & Shrestha, 2017)*

Inkjet water-based inks: Inkjet inks are the most important component in inkjet printing. The formulation and chemistry of inks determine the printing quality as well as jetting characteristics (Tawiah, Ebenezer & Asinyo, 2016). They are inks in which the main carrier is water, the coloring agent is pigment or paint. The color fades quickly, the pigment is more resistant to fading. Water-based inks are inks that are not suitable for non-absorbent surfaces (Uğur, 2018).

Material and Methods

Material

In this study, standard base papers were used for recycling. All chemicals used for recycling are sourced from KSU forest industry engineering laboratories in Kahramanmaraş, Turkey. The optical properties of the base paper are given in Table 1 below.

Table 1

The optical properties of the base paper

Whiteness (% ISO)	Brightness (% ISO)	Yellowness (E313)	CIE Whiteness	L	a	b	Opacity
80.12	98.47	-27.66	145.85	91.74	3.80	-14.29	92.90

Methods

Reference papers were torn into 2x2 cm pieces by hand. Then, these torn papers were pulped in a Hobart type pulping device (Hobart/Germany) according to the 11p standard by the following conditions.

Pulping Conditions Level		Concentration (%)	Time (Min.)
Prewetting	-	10	10
Pulping	1-2	10	22

The pulping chemicals included: sodium hydroxide (0.6%), sodium silicate (1.8%), hydrogen peroxide (0.7%), and oleic acid (0.8%) for standard INGEDE method 11p (Çiçekler & Tutuş, 2019). The purity of the chemicals used are, sodium hydroxide (purity, %98), hydrogen peroxide (purity, %35), sodium silicate (purity, %98), oleic acid (purity, %98).

The pulp, that pulping process was completed, was transferred to the flotation unit and floated at 1% concentration according to the 11p standard for 30 minutes. The pulp the obtained was subjected to a two-stage bleaching process. In the first stage, 4% FAS (formamidine sulfinic acid), and in the second stage, hydrogen peroxide bleaching was applied. Then, test papers were produced from this pulp and their optical-physical properties were determined. The calendering process was applied to the obtained test papers at 100 °C and 20 bar pressure. The produced papers were subjected to physical and optical tests by adhering to the standards after conditioning for 48 hours in an air conditioning room with a room temperature of 25 ± 1 and a relative humidity of 55 ± 1%. The papers obtained after this process were printed with Epson EcoTank L3060 (Epson, Japan) inkjet (water-based ink) and Canon LBP613Cdw laserjet (Canon, Japan) (toner) printers. The ink film parameters of the prints were measured with the X-Rite eXact™ spectrophotometer. In the print quality results, it was tried to reach ISO 12467-2 (International Organization for Standardization, 2013) values. The measured results were repeated 3 times and averaged. Below are the color measurement scales printed on recycled paper in Figure 3.

» **Figure 3:** *Color measurement scales*

Results

Physical and optical properties of recycled papers

The physical properties of the laboratory test paper produced as standard after flotation, bleaching, and calendering processes are given in Table 2.

According to TS 11610: 2017 standard, the minimum values of the physical properties that should be on 80 g writing papers are as follows (Çiçekler & Tutuş, 2019);

- Breaking length (transverse and longitudinal): 2000-4000 meter
- Burst index: 1.3 (kPa m^2/g)
- Bulkiness: 1.2-1.5 (cm^3/g)
- Intensty: 0.6-0.8 (g/cm^3)

When Table 2 is examined, it is seen that the physical properties of the produced test paper after recycling are within the standards. The optical properties of recycled test paper are given in Table 3 below.

The physical and optical properties of a paper are important factors affecting the print quality. For the printing (inkjet, laserjet) conditions to be equal, papers with the same features were produced.

Print properties of recycled paper

Print quality parameters of recycled papers are examined in detail below.

CMYK print density and dot gain

Print density is the amount of ink remaining on the print layer. (Gong, Fleming & Sönmez, 2010). Print density, which is an important factor to be considered for printed products, affects the perceived saturation of a color and is a practical way of evaluating the depth of the tone in the print (Hu et al., 2017). Dot gain, or tonal value increase, is a phenomenon in printing which causes printed material to look darker than intended. It is caused by halftone dots growing in area between the original printing film and the final printed result. In practice, this means that an image that has not been adjusted to account for dot gain will appear too dark when it is printed. Dot gain calculations are often an important part of a CMYK color model. The density and dot gain values of the high-grade paper pulp ISO 12647-2, inkjet and laserjet prints made on recycled papers are given in Table 4 below.

When Table 4 is examined, it is seen that the inkjet and laserjet prints have close to CMYK density values. Nevertheless, it was determined that the density values of laserjet printing in all colors were higher. In both types of printing, it was determined that black color density values were highest and cyan color density values

Table 2

Physical properties of recycled paper

Grammage (g/m^2)	Breaking lenght (m)	Burst index (kPa m^2/g)	Tear index (mN.m^2.g)	Air permeability (m^3/dk)	Intensity (g/cm^3)	Bulkiness (cm^3/g)
88	5466	3.39	6.37	242.91	0.62	1.6

Table 3

Optical properties of recycled paper

Whiteness (% ISO)	Brightness (% ISO)	Yellowness (E313)	CIE Whiteness	L	a	b	Opacity	ERIC (PPM)
73.4	86.01	-20.11	124.99	88.61	3.67	10.86	97.55	251.92

Table 4

Density values for inkjet and laserjet prints

	Print density (%)			Dot gain (%)					
	Inkjet	Laserjet	ISO 12647-2	Inkjet 80 (%)	Inkjet 40 (%)	Laserjet 80 (%)	Laserjet 40 (%)	ISO 12647-2 80 (%)	ISO 12647-2 40 (%)
Cyan	0.94	1.05	1.55	19.43	18.66	18.8	19.9	12	19
Magenta	1.02	1.08	1.20	8.23	7.13	9.43	11.06	12	19
Yellow	1.09	1.14	1.15	19.4	16.6	18.43	18.63	12	19
Black	1.30	1.41	1.20	7.9	1.47	8.73	6.7	14	22

were lowest. When we compare the density values with the following standard values (ISO 12647-2), it is seen that CMY colors are below the standards in both printing types. When we examine the dot gain values, the dot gain was higher in all of the CMYK colors of laserjet printing in the 40 screen area. It is seen that the dot gain in the 80's area is more in cyan and yellow inkjet printing. For printing quality, it is recommended to use a lower screen frequency on matte surface papers. Therefore, it is considered to be more accurate to consider the dot gain measurements made in the 40 screen area. It was observed that the dot gain values measured in the 80 screen area in inkjet printing were outside the standard values. In laserjet printing, the dot gain values of the cyan and yellow colors in the 80 screen area were outside the standards.

CMYK trapping and print contrast

Trapping is the acceptance of a second color overlapping a color in print. Print contrast can be defined as the difference between the darkest and brightest parts of the obtained image in print. For high print quality, it is desirable to have high print contrast. The properties of the paper are the most important factors affecting the printing contrast (Sönmez, 2011). The trapping and print contrast values of inkjet and laserjet prints made on recycled papers are given in Table 5 below.

Table 5

Trapping and print contrast values of inkjet and laserjet prints

Trapping (%)			Print contrast (%)		
			Color	Inkjet	Laserjet
Color	**Inkjet**	**Laserjet**	Cyan	11.03	9.63
M+Y	28.23	92.2	Magenta	38.60	38.17
C+Y	76.90	98.17	Yellow	12.90	13.33
C+M	55.37	94.07	Black	49.03	47.07

When Table 5 is examined, it is determined that the trapping values of laserjet printing give much better results on recycled papers. In inkjet printing, magenta + yellow colors are determined as the lowest acceptance rate, and cyan + yellow colors are determined as the highest rate in laserjet printing. Trapping values the 70-75% range is accepted as standard. This value is requested to be high. Less than 65% is considered insufficient (Yılmaz, 2016). According to standard values, the best result in trapping values is the C+Y colors of laserjet printing. The worst result is the M+Y colors of inkjet printing. When the print contrast values and the surface properties of the paper are examined, it is seen that the results obtained are ideal. Although there is not a big difference, it is seen that inkjet printing has superior performance, even if it is very small, in terms of print contrast to laserjet printing. In both printing types, the printing contrast values of cyan and yellow color were below the standard values. It has been observed that inkjet printing values are higher in cmk colors and laserjet printing has a superior performance in yellow. Magenta and black colors are seen to be in standard and desired values (Yılmaz, 2018).

CMYK gloss and print chroma

Gloss measurements were made with a BYK Gardner GmbH gloss meter according to ISO 2813:2014 (International Organization for Standardization, 2014), 60° geometry (Özcan et al., 2019). Chroma means color saturation and can be measured by the color intensity channel. Chroma values that are decisive for print quality are desired to be high (Sönmez, 2011). The gloss and print chroma values of inkjet and laserjet prints made on recycled papers are given in Table 6 below.

Table 6

Chroma and gloss values of inkjet and laserjet prints

	Gloss			Print chroma	
	Paper	**Inkjet**	**Laserjet**	**Inkjet**	**Laserjet**
Cyan	4.17	2.53	4.23	44.03	48.09
Magenta	4.17	2.37	4.63	53.40	56.09
Yellow	4.17	3.73	6.10	67.45	72.28
Black	4.17	1.47	4.03	2.90	1.81

When Table 6 is examined, it can be seen that the gloss values of laserjet printing perform better. The gloss of the laserjet print in black was found to be almost 3 times the gloss of the inkjet print. In Magenta color, this ratio was found almost 2 times. It is seen that the highest value is yellow in laserjet printing, and the lowest value is black in inkjet printing. When the chroma values are analyzed, we can see that laserjet printing produces better results in recycled papers. In black, it is seen that inkjet printing has a higher value than laser jet. It is seen that laserjet printing has an obvious advantage in CMY colors.

CIE L*, CIE a* and CIE b* values and color gamut

CIE is designed many colour universe models over time. Although these different in technological development processes, the basis is colour, saturation and brightness properties. The main purpose of CIE is to create a repeatable system of colour communication standards for material manufacturers such as paint and ink. Providing a universal template for colour matching is the most important function of these standards (Nussbaum, 2010). As a result, simple values can be used to describe the adjectives red/green and yellow/blue. This color pattern is often used as the basis for color vision (Mokrzycki & Tatol, 2009). In CIE L* a* b*, L* shows lightness, a red/green, b* yellow/blue (Köse & Şahinbaşkan, 2008).

L* a* and b* values measured for color gamut and printing chroma values are given in Table 7 below.

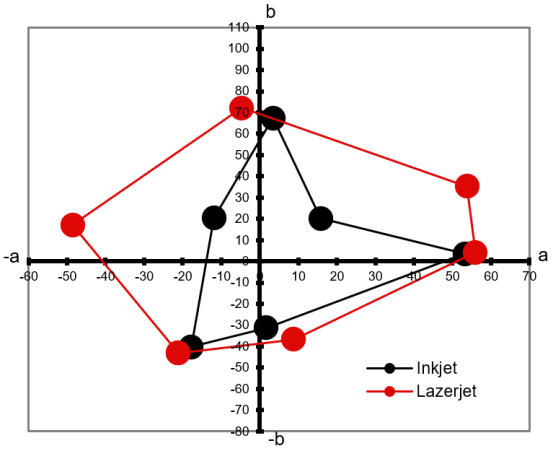
Table 7

L*, a* and b* values of inkjet and laserjet prints

	Inkjet			Laserjet		
	L*	**a***	**b***	**L***	**a***	**b***
C	57.51	-17.74	-40.25	55.16	-21.16	-43.13
M	53.1	53.27	3.49	51.14	55.90	4.31
Y	81.63	3.41	67.37	83.53	-4.68	72.12
K	31.90	2.82	0.64	26.32	1.76	0.36
R	56.18	15.80	20.20	48.64	53.79	35.32
G	56.59	-11.90	20.34	47.10	-48.57	17.06
B	41.64	1.71	-31.30	30.98	8.80	-36.64

As it is known, color gamut and print chroma values are measured by means of L* a* b* values. When we examined the L* values of both prints, it was seen that the inkjet printing values were higher in c, m and k colors. It has been determined that the yellow color has a higher L* value in laserjet printing. When we examine the a* values, it was determined that the C, Y and K colors are higher in inkjet printing. When we examine the b* values, it was determined that the inkjet printing value in cyan and black color is high, and the laserjet printing value is high in magenta and yellow color. It was determined that the laserjet printing value was higher in magenta color. When we look at the color gamut, it has been observed that laserjet printing reaches a wider color spectrum.

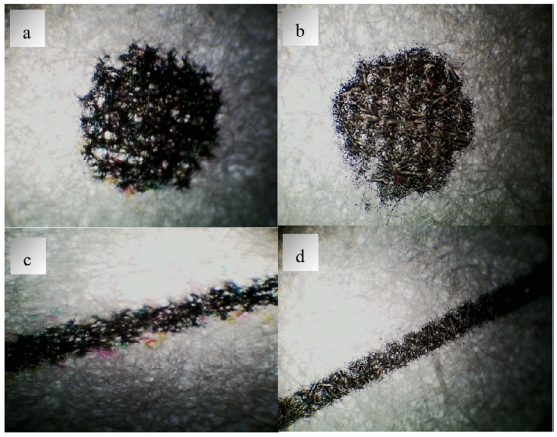
Gamut refers to the RGB colors, which are the computer format of the colors to be printed. It also express to all the shades of CMYK colors, which are the format on the print material, in the gamut. While creating the color gamut, the RGB color space must be converted to the CMYK color space. It can be defined as follows; On the highest level, the aim of color gamut "is to ensure a good correspondence of overall color appearance between the original and the reproduction by compensating for the mismatch in the size, shape and location between the original and reproduction gamuts (Morovic & Luo, 2001). In addition, the color gamut can be defined as the range of colors that a particular device can produce or save. If the Gamut value is high, the color gamut obtained in printing will be so wide (Yılmaz, 2018; Chen, Berns & Taplin, 2004). In order to create a color gamut, L*a*b* values of both CMYK and RGB colors were measured with X-Rite eXact™ Spectrophotometer (D50 illuminant, 2° observer, 0°/45° geometry, black backing). In the second stage, a pivot table was created in the excel program. The color gamut was obtained by entering the measured lab values into the created pivotable. When we examine Figure 4, we can see that the color gamut of laserjet printing reaches a much higher area than the color gamut of inkjet printing. The wider the color gamut, the greater the color processing and image quality. In this case, it is seen that laserjet has a much wider color diversity than inkjet.



» **Figure 4:** *Color gamut of inkjet and laserjet prints*

Examination of microscope images

Binocular Light Microscope with 2000x Magnification microscope was used for these images. These images were made at coaxial coarse and fine focus settings. Coarse adjustment working distance: 36mm, fine adjustment working distance: 0.002mm.



» **Figure 5:** *0.1 pt. dot (4x), (a; inkjet, b; laserjet), 0.5 pt. line (4x) (c; inkjet, d; laserjet)*

When the Figure 5 magnified 4 times (4x) is carefully examined, it is seen that a clearer print is obtained with Laserjet printing from both 0.1 point dot and 0.5 point line printing.

Conclusions

It is known by everyone that the recycling of paper is very important both in terms of cost and conservation of natural resources. In addition, secondary fibers obtained from recycled papers are considered not to have the print quality as much as paper made from primary fibers. In this study, inkjet and laserjet print-

ing properties of recycled papers were determined. According to the study data; It has been observed that there is a certain difference in inkjet and laserjet printing density of recycled papers. It has been observed that dot gain values of laserjet printing are higher than inkjet printing. When the trapping values are examined, the obvious superiority of laser printing over inkjet printing is noted. Although there is not a huge difference in value in print contrast, it is seen that the inkjet performs better than laserjet printing. When we look at the gloss values of recycled papers, laserjet printing has been observed to give better results. When the print chroma values were examined, it was determined that the laserjet printing was higher in the CMY colors and the inkjet printing was higher in the black color.

As a result, it has been determined that both printing systems dominate each other in different printing parameters. Considering all the data, it has been seen that inkjet and laserjet prints have appropriate results in terms of print quality in the recycled paper in general.

Acknowledgements

The authors thank Kahramanmaraş Sütçü İmam University Scientific Research Projects Unit for supporting this study with the project number 2019 / 1-13D.

References

Chen, Y., Berns, R. S. & Taplin, L. A. (2004) Extending Printing Color Gamut by Optimizing the Spectral Reflectance of Inks. In: *CIC 2004: The Twelfth Color Imaging Conference: Color Science and Engineering, CIC 2004, 9 November 2004, Scottsdale, Arizona.* Springfield, IS&T- The Society for Imaging Science and Technology.

Çiçekler, M. & Tutuş, A. (2019) Atık GazeteKağıtlarının Geri Dönüşümü Üzerine Bir Araştırma. In: *AGRIFOR: International Congress on Agriculture and Forestry Research, AGRIFOR, 8-10 April 2019, Marmaris, Turkey.* Marmaris, AGRIFOR. pp. 125-135.

Enviromental Paper Network (2018) *The State Of The Global Paper Industry.* Enviromental Paper Network.

European Paper Recycling Council (2017) *Monitoring Report 2017 European Declaration on Paper Recycling 2016-2020.* Brussels, European Paper Recycling Council.

Gong, R., Fleming, P. D. & Sönmez, S. (2010) Application Of Nano Pigments İn Inkjet Paper Coating. In: *NIP26: 26th International Conference On Digital Printing Techologies, NIP26, 19-23 September 2010, Austin, Texas.* Springfield, IS&T- The Society for Imaging Science and Technology. pp. 507-511.

Hoffman, M. (2005) *Digital Printing Technology and Printing.* Poing, Oce Printing Systems GmbH.

Hu, G., Fu, S., Chu, F. & Lin, M. (2017) Relationship between Paper Whiteness and Color Reproduction in Inkjet Printing. *Bioresources.* 12 (3), 4854-4866, Available from: doi: 10.15376/biores.12.3.4854-4866

International Organization for Standardization (2014) ISO 2813:2014. *Paints and varnishes - Determination of gloss value at 20 degrees, 60 degrees and 85 degrees.* Geneva, International Organization for Standardization.

International Organization for Standardization. (2013) ISO 12647. *Graphic Technology, Process Control For The Production Of Half-Tone Colour Separations, Proof And Production Prints.* Geneva, International Organization for Standardization.

Jurič, I., Karlovits, I., Tomić, I. & Novaković, D. (2013) Optical paper properties and their influence on colour reproduction and perceived print quality. *Nordic Pulp and Paper Research Journal*. 28 (2), 264-273. Available from: doi: 10.3183/npprj-2013-28-02-p264-273

Karademir, A., Karahan, S., Imamoglu, S., Ertas, M., Aygan, A., Aydemir, C. & Pesman, E. (2013) Use of enzyme and ultrasonic energy in paper recycling. *Journal of History Culture and Art Research.* 1 (4), 280-297. Available from: doi: 10.7596/taksad.v1i4.127

Karasu, B., Karabulut, D., Biçer, A., Varol, U. C. & Oytaç, Z. E. (2019) Seramik Sektöründe İnkjet Dekorasyon Uygulamaları. *El-Cezerî Journal of Science and Engineering.* 6 (3), 691-711. Available from: doi: 10.31202/ecjse.572176

Köse, E. & Şahinbaşkan, T. (2008) Renk Yönetiminde Kullanılan Standart ICC Profillerinin Türkiye'de Oluşturulmuş Bazı Profillerile Karşılaştırılması. *Politeknik Dergisi.* 11 (4), 365-371.

Lau, G. K. & Shrestha, M. (2017) İnkjet Printing of Micro-Electro-Mechanical Systems (MEMS). *Micromachines.* 8 (6), 194. Available from: doi: 10.3390/mi8060194

Mauchaufé, R., Lee, S. J., Han, I., Kim, S. H. & Moon, S.Y. (2019) Improved de-inking of inkjet-printed paper using environmentally friendly atmospheric pressure low temperature plasma for paper recycling. *Scoemtofoc Reports*. 9. Available from: doi: 10.1038/s41598-019-50495-4

Mokrzycki, W. & Tatol, M. (2009) Perceptual difference in L*a*b* color space as the base for object colour identfication. In: *1'st International Conference on Image Processing & Communications, August.* Available from: doi: 10.13140/2.1.1160.2241

Morovic, J. & Luo, M. R. (2001) The Fundamentals of Gamut Mapping: A Survey. *Journal of Imaging Science and Technology.* 45 (3), 283-290.

Nussbaum, P. (2010) *Colour Measurement and Print Quality Assessment in a Colour Managed Printing Workflow.* PhD thesis. Gjovik University College.

Ozcan, A., Kandirmaz, E. A., Hayta, P. & Mutlu, B. (2019) Examination Of The Effect Of Melamine As A Filler In Paper Coatings On Print Quality. *Cellulose Chemistry And Technology.* 53 (3-4), 307-313. Available from: doi: 10.35812/CelluloseChemTechnol.2019.53.30

Romano, F. J. (2000) *Digital Printing.* San Diego, Windsor Professional Information.
Sönmez, S. (2011) Interactive Effects Of Copolymers And Nano-Sized Pigments On Coated Recycled Paperboards İn Flexographic Print Applications. *Asian Journal Of Chemistry.* 23 (6), 2609-2613.
Tawiah, B., Ebenezer, K. & Asinyo, B. K. (2016) The Chemistry Of Inkjet Inks For Digital Textile Printing. *BEST: International Journal of Management, Information Technology and Engineering.* 4 (5), 61-78.
Tuncel, O. (2019) Dijital Çağda Baskı Teknolojileri. *Sanatve Tasarım journal.* (23), 361-377.
Tutak, D. (2015) Modified Deinking Of Digitally Printed Paper With Water Based Inkjet Ink. *Cellulose Chemistry And Technology*. 51 (5-6), 483-488.
Uğur, E. (2018) İnkjet (Mürekkep Püskürtmeli) Dijital Baskı Teknolojilerin Çalışma Sisteminin Tanımlaması ve Kullanım Alanlarının Kategorizasyonu. *Journal Of Social, Humanities And Administrative Sciences.* 4 (10), 75-85. Available from: doi: 10.31589/JOSHAS.40
Yılmaz, U. (2016) *Bazi Kağitlarin Fiziksel Özelliklerinin Offset Baski Kalitesine Etkisinin İncelenmesi.* MSc thesis. Kahramanmaras Sutcu Imam University.
Yılmaz, U. (2018) Investigation of The Effect on Print Contrast of Optical Properties of Paper in Offset Printing. In: *6th International Printing Techologies Symposium, 1-3 November 2018, Istanbul, Turkey*. Istanbul, Istanbul University. pp 1165-1171.

http://doi.org/10.24867/JGED-2021-3-013

Identifying competencies for future graphic design graduates in Malaysia: A Delphi study

ABSTRACT

Traditionally, graphic design (GD) education focuses on the training of technical production skills to prepare graduates for entry-level employment. However, due to the new challenges and the expanding opportunities of emerging practices, GD graduates are expected to master a wide range of additional competencies beyond traditional scope. The study aims to identify the competencies required by future GD graduates in the context of Malaysia. A two-round modified Delphi technique was used to gain consensus from a panel of experts consisted of design educators and industry practitioners regarding the competencies needed by the graduates for effective work performance. A total of 108 competencies were generated. All accepted competencies were ranked 'very important' and 'extremely important' by at least 75 percent of the respondents in Round Two. These competencies could be classified into 29 subdomains under five components, i.e., cognitive competence, functional competence, personal competence, ethical competence, and meta-competencies. The findings of this study are useful for enhancing the education and employability of graphic designers as they provide a common vocabulary to relevant stakeholders about the standards of performance for new entrants to the GD profession.

KEY WORDS
modified Delphi technique, graphic design graduates, cognitive competence, functional competence, personal competence, ethical competence, and meta-competencies, Malaysia

Shaw-Chiang Wong [1]
Muhammad Zaffwan Idris [2]
Wee-Chuen Tan [1]

[1] Raffles University, Faculty of Art and Design, Johor Bahru, Malaysia
[2] Universiti Pendidikan Sultan Idris, Faculty of Art, Computing and Creative Industry, Tanjong Malim, Malaysia

Corresponding author:
Wong Shaw Chiang
e-mail: wongshawchiang@raffles-university.edu.my

First received: 22.3.2021.
Revised: 21.5.2021.
Accepted: 4.06.2021.

Introduction

The demands on the professional practice of GD in the 21st century bear little resemblance to those of the past (Heller, 2015). Traditionally, graphic designers have often been viewed as 'craftsmen' or 'decorators' who focus on 'the making of things and beautiful things' (American Institute of Graphic Design (AIGA), 2015a). Rapid development in technology and industry has expanded the scope and content of graphic designers' work (Dziobczenski & Person, 2017; Harland, 2016). Nowadays, graphic designers are found to work in areas such as service design, strategic planning, innovation management, branding, and technology development (Davis, 2017). Approaches and strategies in design have also been gradually shifted from designer-oriented to user-centred, intuition-based to research-driven, and single-disciplinary work to interdisciplinary collaboration (Muratovski, 2016). To meet the changing demands in practice, designers are required to adapt and acquire a new range of competencies in a broader range of disciplines and fields (Kiernan & Ledwith, 2014).

However, there is little updated information on the current employment requirements of graphic designers in education (Cheung, 2016; Davis, 2015; Marks, 2015; Swanson, 2015). To date, technical production skills, including strategies in visual composition, principles of typesetting, and understanding of print processes remain the training priorities in the GD programmes of many universities (Davis, 2005, 2017; Frascara, 1988). Consequently, students are mostly ill-prepared for the

skills, knowledge, and abilities needed to deal with the changing demands in design practice upon graduation (Heller, 2005b; Hsieh, Guan & Wu, 2010) and eventually "end up in roles where they design according to a set of given instructions" (Lim, 2015, p.58). Since the students are trained to fulfil yesteryears' needs, there is a growing concern about whether formal GD education is still necessary (Chiang, Idris & Chuen, 2018). Such concern is raised because there is an increasing number of 'self-taught' or 'informally trained' designers who learn design software independently themselves and work effectively as 'graphic designers' in the industry (Okyere, 2017).

In general, there are no prescribed professional standards to guide the development of academic programmes in GD at university level (Cheung, 2011; Chiang, Idris & Chuen 2019). Although GD programmes offer more or less the same introductory courses, students are taught differently from university to university (Wilson, 2014). Levels of teaching excellence and graduates' quality also vary between universities (Debbie, 2011). As highlighted by Heller (2015), "Unlike degree programs for professions governed by established standards and standardized test (i.e., law, medicine, engineering, psychology, economics), graphic design – which does not, and perhaps may never, necessitate broad-tested certification – has very few strict curriculum conventions and hardly any blanket requirements (other than "knowing" the computer and being "fluent" in type)" (p. 12). Since the job scope of graphic designers today is far more complicated and broader than before, the absence of prescribed professional standards creates difficulties in developing the most relevant curricula for those who wish to practice in the field of GD (Higgins, 2008).

The conflict between educators and industry practitioners have always been an issue in the GD field (Bridges, 2013; Dziobczenski & Person, 2017). Question about what skills and knowledge should be taught to best prepare the students for their professional careers remains a popular topic of debate and discussion between both parties. Wang's (2006) study exemplified this and found out that while industry practitioners focused more on mastery of competencies that are more task-oriented, design educators emphasized more on knowledge-based competencies. Cheung's (2016) study also suggested that "the criteria of competence held by design academia and those held by industry [in Hong Kong] were different: the differences between broader objective and narrower subjective business measures" (p. 37). However, most educators and industry practitioners involved in the study failed to aware of this 'blind spot'. As a result, a 'knowledge gap' seems to appear when university students enter the actual workplace. Cheung's (2016) findings echoed the concern of Eraut (2007) that the primary challenge university graduates experience during the early period of professional learning and development is the "different types of discourse and epistemologies" (p.116). In this case, educators and practitioners need to come to some 'agreements' regarding the competencies expected for new entrants to the GD profession to fill the 'knowledge gap' and thereby enhancing the educational and employability process (Chiang, Idris & Chuen, 2018) as well as strengthening the status of GD as an academic and professional discipline (Dziobczenski & Person, 2017).

Although a number of studies had been conducted to identify the knowledge, skills, traits, and abilities required by GD graduates in different geographical regions (e.g., Bridges, 2013; Cheung, 2016; Dharavath, 2003; Dziobczenski & Galeotti, 2017; Dziobczenski et al., 2018; Hsieh, Guan & Wu, 2010; Wang, 2006; Wilson, 2014), ethics and values are being paid relatively less explicit attention in these studies. However, design scholars (e.g., Berman, 2009; Heller & Vienne, 2003; McCollam, 2014; Perkins, 2011) and design associations (e.g., AIGA, 2010; wREGA, 2012; International Council of Design (ico-D), 2011; GDC, 2012) have highlighted their significance to professional practice and development in the GD field. This means that both ethics and values are important competencies that should be introduced to students while studying at university.

Both Bridges (2013) and Wang (2006) suggested that due to the rapid advancement of technology and expansion of global consumer market, more studies on GD competencies should be done in different geographical regions to ensure up-to-date curriculum is always ready for various stakeholders. Up to the best notice of the authors of this study, very few related studies have been done in developing countries such as Malaysia. Therefore, this study aims to identify the essential competencies that should be possessed by future GD graduates for effective work performance in the context of Malaysia.

Research Methods

Modified Delphi Technique

Delphi technique was used to gather information from a group of experts through several rounds of questionnaires to formulate a consensus among them (Delbecq, VandeVen & Gustafson, 1975). According to Clayton (1997), the Delphi technique has three distinctive characteristics: anonymity, interaction with controlled feedback, and statistical group response. Individuals are allowed to share their views in an environment that is free of hostility, social pressure, and individual dominance as participant anonymous is generally secured during the group communication process (Andrews & Allen, 2002). Although Delphi technique is time-consuming (Powell, 2003), it is more cost-effective when a large number of individuals are required to comprehensively investigate an issue (Linstone & Turoff, 1975).

In this study, a two-round modified Delphi was used to gain consensus from a group of experts about the competencies needed by future GD graduates in Malaysia. In comparison to a conventional Delphi that requests the experts to answer a set of open-ended questions in the first round, a 'modified' Delphi starts with a set of carefully selected items for them to review (Custer, Scarcella & Stewart, 1999). These items can be created through extensive literature review, document analysis, consultation with experts, or adaptation of previously validated questionnaire (Bridges, 2013; Stahl & Stahl, 1991; Wang, 2006). The initial competency items of the Delphi Round One of this study was produced from the review of existing literature.

Delphi Panel Selection

To ensure the quality of collected data, it is important to select the most qualified experts in the subject matter (Mullen, 2003; Ogbeifun et al., 2016). However, participant response rates have always been regarded a key concern (Hasson, Keeney & McKenna 2000) because a Delphi study usually takes up a great deal of time (Powell, 2003). Delbecq, Van deVen, and Gustafson (1975) suggested that for experts to stay active throughout the study, they must be well-informed of the aim of the study, feel personally attached with the issue under investigation, have meaningful insights to share, and understand their contribution to the results of the research.

In this study, the experts were categorized into two groups: university-level design educators and industry practitioners. They were selected using non-probability purposive sampling technique (Cohen, Manion & Morrison, 2000). In specific, snowball sampling technique was used to select the most suitable panel experts. According to Cohen, Manion and Morrison (2000), snowball sampling is a sampling technique where the researcher identifies a small number of individuals as key informants to recommend other qualified persons in the population to participate in the study.

22 design educators who are working at either private or public higher educational institutions (HEIs) in Malaysia, teaching bachelor's degree programmes in visual communication design, digital and interactive design, and advertising design were recruited to participate in this study. 17 industry practitioners who are from various areas such as graphic communication design, brand and identity system design, advertising design, publication design, and interactive design, were recruited with the recommendation from the board members of the Graphic Design Association of Malaysia (wREGA).. A total of 39 GD experts agreed to participate in this study.

Instrumentation: Delphi Round One and Round Two

The Delphi Round One questionnaire contained three parts. Part One consisted of a set of demographic questions. Part Two comprised a list of pre-determined competency items, which were created from the review of existing literature. The initial 125 items were classified into 33 subdomains under five competency components proposed by Cheetham and Chivers (1996; 1998), i.e., cognitive competence, functional competence, personal competence, ethical competence, and meta-competencies. A short description was given to the components and subdomains to ensure all experts were on the same page when ranking the items. The experts were requested to rank the items based on a 5-point Likert scale according to their level of importance, where: 1 = Not at all important; 2 = Not so important; 3 = Somewhat important; 4 = Very important; and 5 = Extremely important. In addition, participants were also allowed to give comments for each item in a 'comment box'. Part Three consisted of an open-ended question for the experts to suggest any other extra competencies that should be considered by the study in Round Two.

The format and questions of the Round Two were identical to Round One. However, it only consisted of a questionnaire prompting participants to rank the competency items.

The questionnaires were designed through SurveyMonkey, an online survey development cloud-based software. Each questionnaire was examined by two experts in research methods to ensure the clarity and validity of the questions as well as the ease of use of the online survey design.

Acceptance and Removal Criterion

There is no agreed-upon consensus level in the literature for Delphi studies (Keeney, Hasson & McKenna, 2001; Powell, 2003). Keeney, Hasson and McKenna (2001) noted that the consensus level could be guided by the significance of the topic. According to them, 100 percent consensus may be required for life and death issues, while 51 percent may be suitable for preferences.

To gain consensus among the experts to identify the most relevant competencies, a cut-off level of the items ranked 'very important' and 'extremely important' was used in this study. An item must be ranked at four or greater by at least 75 percent of the respondents. This acceptance criterion was also used in previous Delphi studies (e.g., Al-Muallem et al., 2016; Arbabisarjou et al., 2016; Johnston et al., 2014). Those items that cannot meet the acceptance criterion would be removed from the competency list eventually. However, an item would be removed 'immediately' from

the questionnaire in Round Two if it was ranked 'not so important' or 'not at all important' by at least 75 percent of the respondents in the Round One. This is because such an item might achieve very low agreement on its level of importance or relevance among the experts who participated in this study.

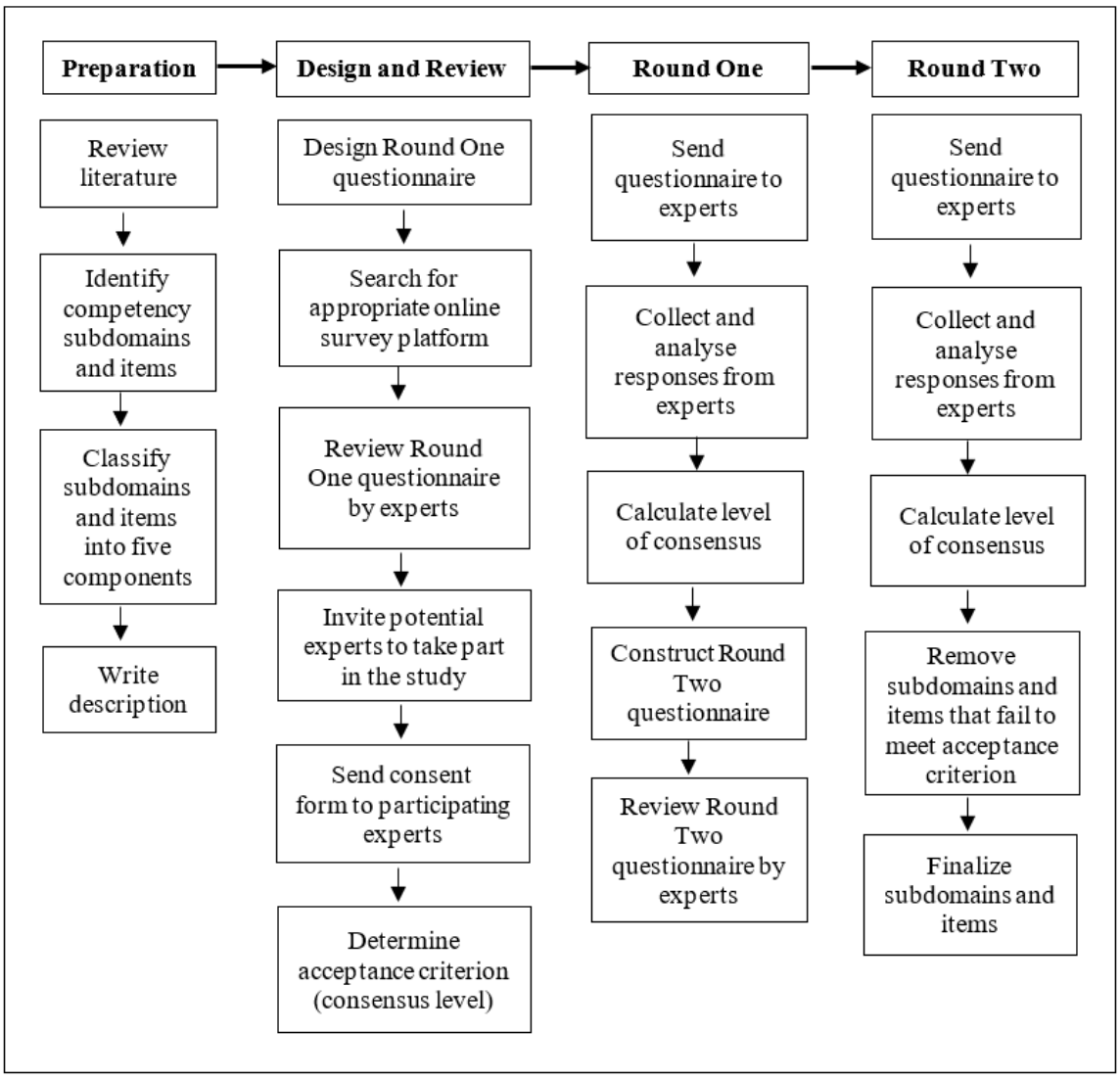
Frequencies of each item were calculated by using Statistical Package for the Social Sciences (SPSS) version 21. Figure 1 illustrates the overall modified Delphi process used in this study.

Results

Round One

Round One questionnaire was accessible to all panel experts for a period of three weeks. One more week was extended to increase the response rate. Of the 39 experts who initially agreed to participate in the study, 35 responded, which yielded a total response rate of 89.7 percent. In specific, 21 (60%) were design educators and 14 (40%) were industry practitioners. Based on this response rate, at least 26 panel members would have had to rank a competency item at four or greater for acceptance. The overall acceptance rate in Round One was 79.2%. Of the initial 125 items, 99 items were ranked 'very important' or 'extremely important' by at least 26 respondents (75%) in Round One.

Based on the results, only one or none of the item in the following competency subdomains met the acceptance criteria: 'art and design history', 'business fundamentals', 'user-centred design skills', 'data visualisation skills', 'research skills', 'software skills', and 'design thinking skills'. This means that these subdomains might be removed from the list if the results remained the same in Round Two. None of the items in



» **Figure 1:** *The modified Delphi process used in gaining experts' consensus on competencies required by future graphic design graduates*

Round One met the immediate removal criteria. Therefore, all items were 'temporarily' included for further reviewed in Round Two. After considering the comments received in Round One, nine new items were added and 34 existing items (27.2%) were modified. In addition, it was found that no new competency subdomain appeared from the analysis of experts' comments.

Round Two

Round Two questionnaire was accessible to all panel experts for a period of three weeks. One more week was extended to increase the response rate. 32 experts completed the questionnaire. Specifically, 19 (59.4%) were design educators and 13 (40.6%) were industry practitioners. This means that a competency item would have had to be ranked at four or greater by at least 24 panel members for acceptance.

Following the analysis of the Round Two, this study produced a final list of 108 competencies, which could be categorized into 29 subdomains under five competency components (Table 1).

It was worth noting that 26 items (19.4%) were deleted after the analysis of the experts' responses in Round Two. This had resulted the removal of four competency subdomains: 'art and design history', 'user-centred design skills', 'data visualisation skills', and 'research skills'.

Table 1

Competencies for future graphic design graduates

1.0 Cognitive Competence
The mastery of work-related knowledge, awareness, understanding or information, and the capability to apply them in given work-related situations effectively.
1.1 Design Fundamentals (3)
1.2 Industry Knowledge (4)
1.3 Contextual Awareness (4)
1.4 Multidisciplinary Knowledge (2)
1.5 Business Fundamentals (3)
1.6 Marketing Fundamentals (3)
2.0 Functional Competence
The ability to successfully perform a variety of work-related tasks using available tools and technologies in order to achieve specific outcomes.
2.1 Technical Design Skills (3)
2.2 Conceptual Design Skills (4)
2.3 Interactive Design Skills (3)
2.4 Advertising Design Skills (3)
2.5 Software Skills (3)
2.6 Graphic Print Production Skills (4)
2.7 Project Management Skills (5)
3.0 Personal Competence
The acquisition of appropriate traits, social behaviours, desires, psychological impulses or emotions in work-related situations.
3.1 Aesthetic and Visual Sensitivity (3)
3.2 Self-driven (3)
3.3 Adaptability and Flexibility (3)
3.4 Emotional Intelligence (4)
3.5 Interpersonal Skills (3)
3.6 Self-efficacy (3)
4.0 Values / Ethical Competence
The acquisition of professional behaviours, knowledge, and values for making mindful decisions in assigned occupational contexts.
4.1 Professional Behaviours (9)
4.2 Professional Expertise (5)
4.3 Professional Values (3)
5.0 Meta-competencies
Those generic and overarching 'soft-qualities' that are deeply embedded in learning and enable introspection and self-assessment. They are of a higher level than other competencies and are able to support the acquisition and development of other competencies.
5.1 Creative Thinking Skills (3)
5.2 Problem Solving Skills (3)
5.3 Design Thinking Skills (3)
5.4 Critical Thinking Skills (4)
5.5 Reflective Thinking Skills (4)
5.6 Communication Skills (7)
5.7 Teamwork and Leadership Skills (4)

Discussion

Although collaboration between educators and industry practitioners has long been in existence, such a relationship has always been regarded as complicated. The conflict between both parties continues to be an issue, and this is not exempted in the GD discipline. Incompetent performance of graduates in the workforce is believed to be the main cause of this conflict (Bridges, 2013; Cheung, 2011). Previous studies exemplified that both parties have different expectations when it comes to what types of knowledge, skills, and abilities should be possessed by GD graduates to perform effectively in the industry (e.g., Cheung, 2016; Dziobczenski & Galeotti, 2017; Wang, 2006). Nevertheless, it is not wise to isolate the industry's expectations from design education or vice versa (Butler, 1995). On the one hand, the realistic expectations of the industry must be considered in design education (Lewis & Bonollo, 2002) to make sound curricular decisions (Dharavath, 2003; Wilson, 2001) and to enhance the career prospects of design graduates (Davis, 2005). On the other hand, educators are urged to fulfil not only the short-term expectations of the industry but also prepare students for the long-term needs of their lives and for making positive changes in society (Chiang, Idris & Chuen, 2018; McCoy, 1990).

Therefore, this study aims to create a 'platform' for both parties to 'communicate' with each other to achieve some agreements regarding what competencies should be demonstrated by future GD graduates. In such a context, Delphi technique was chosen as the research method of this study. Findings showed that design educators and industry professionals in Malaysia did share similar views on the importance of certain competencies.

In general, the findings of this study echoed the results of several studies that GD graduates in the future need to be multi-skilled to begin professional practice (e.g., Adu, 2015; Dziobczenski & Person, 2017; Dziobczenski, Person & Meriläinen, 2018). Apart from mastering technical design skills and having good visual sensitivity, the graduates are expected to display a wide range of additional skills, knowledge, and personal traits such as industry knowledge, contextual awareness, multidisciplinary knowledge, business fundamentals, marketing fundamentals, self-driven, self-efficacy, emotional intelligence, and adaptability and flexibility to meet the changing demands in the practice. Overall, the competency subdomains and competencies uncovered provide a shared perspective among the experts in association with the intended qualities and outcomes that GD education at the university level should produce.

GD has always been related to print technology. As technology advances, interaction and user participation have become increasingly common in print design (Neves, 2017). Based on the findings, while graphic print production skills remain relevance, experts in Malaysia also expressed the importance of interactive design skills and UI and UX software skills for future graduates to catch up with the emerging trends in design. In other words, graphic designers who possess the abilities to deal with digital and interactive jobs are in more demand by the industry in Malaysia. This is in consistent with the comments or findings of several studies and reports that networked communication design and software development positions will grow in the years to come (e.g., Davis, 2017; Heller, 2015; United States Bureau of Labour Statistics, 2017). However, user-centred design skills and its related competencies, which can be used to support the interactive design process, were ranked less important by the experts, and were consequently removed from the functional competence component. It is difficult for designers to produce a satisfying and meaningful interactive experience without having skills in empathizing and evaluating the needs of end-users.

In addition, the study also found that project management skills, teamwork and leadership skills, and interpersonal skills are important to the graduates, suggesting that they may assume a more strategic or leading role in the industry in the future. Similar results had also been demonstrated in studies such as Perks, Cooper & Jones (2005) and Valtonen (2005) on the product and industrial designers' roles. In other words, apart from fulfilling operational or outcome-related role, such as to produce physically appealing products, GD graduates will most likely be given more opportunities to participate in strategic planning for effective design solutions in the industry. In supporting of this assumption, communication skills, problem-solving skills, critical thinking skills, creative thinking skills, design and innovative thinking skills, and reflective thinking skills were also viewed as highly important by those GD experts involved in the study.

While a number of reports and studies especially in western regions had highlighted the relevance of data visualization and research skills for graphic designers to fulfil the expectations placed upon them in the future (e.g., Davis & Littlejohn, 2017; Dziobczenski et al., 2018; Muratovski, 2016; Walker, 2017), they failed to meet the acceptance criterion and were therefore removed from the functional competence component. Moreover, history of art and design was also excluded by experts from the cognitive competence component. This reflected the concern of Heller (2005a) that the value of art and design history has often been underappreciated in the education of graphic designers. However, Hollis (2015) noted that understanding of art and design history not only gives students the confidence to think and discuss their work, it can also assist graphic designers in creating values and address questions associated with design style. Based on the findings, it can be assumed that art and design history is overshadowed by other practical competencies. It is

a 'nice to know' but not a 'must know' area in modern design practice. This assumption can be summed up by considering a comment given by a participating expert,

> *It is good for [graphic] designers to 'know' or 'understand' art and design history… But I am having doubt if it is an 'important' area of knowledge that needs to be applied in the practice, especially in the context of Malaysia.*

McCollam (2014) claimed that ethical aspects have often been overlooked in the education of designers, including GD. Previous studies (e.g., Chiang, 2019; Chiang et al., 2016) also suggested that from lecturers' and students' perspectives, social responsibility dimensions were not comprehensively integrated into GD curriculum in Malaysia. However, the findings of this study officially acknowledge the significance of ethical behaviours, expertise, and values in the professional practice of GD in Malaysia. For the graduates to comply with the ethical standards of the practice, they must be introduced to and aware of their responsibilities to commercial clients, other graphic designers, public, society, and environment at the university level. As noted by Berman (2013), to perform ethically in design practice "will elevate both the real and perceived value of design and designers, while helping to ensure that design is serving the social good. It's also an important step towards certification of the profession, which is ultimately what will benefit Malaysia and its designers the most" (p. 56). GD programmes providers must strive their best to identify a better way to nurture 'citizen designers' who have the abilities to produce good design (Berman, 2009, 2013; Heller & Vienne, 2003; McCoy, 2003; Whiteley, 1993)

Limitations and Recommendations

Although this study uncovers valuable information, it does have its limitations. First, the Delphi is a very time-consuming research method (Powell, 2003); therefore, it was challenging to acquire qualified design educators and industry practitioners for this study as well as to sustain their commitment throughout the data collection process due to their hectic schedule. Although 39 experts in the field agreed to take part in this study, the highest response rate reached was in Round One, with only 35 experts completing the questionnaire. It was acknowledged by the authors of this study that it would not be appropriate to generalize the findings broadly without further validation of the identified competencies using a larger sample.

Second, very limited written feedbacks and comments were provided by the participants in Round One. Consequently, no new competency subdomains appeared in Round Two and the competency items in Round Two were almost the same with those in the Round One questionnaire.

Accordingly, more participants can be recruited in the future while conducting similar studies as the bigger the sample size, the more reliable of the Delphi studies' results (Hasson & Keeney, 2011). With a larger sample size, it will be highly beneficial to determine the ranking of importance of the competency subdomains. In addition, though Delphi technique is proven to be a useful method to collect data for related studies, it will be interesting to use other qualitative methods such as face-to-face interview or focus group discussion to add valuable insights to the study.

It is also recommended to conduct an evaluation for university-level GD programmes using the competencies identified in this study as prescribed standards of performance. The findings can also be used as a preliminary diagnostic tool to assess the competency levels of GD students. However, additional studies should be done to further validate the findings of this study.

Lastly, as technology continues to progress, it will be necessary to ongoingly evaluate and expand the findings of this study in Malaysia and in other geographical regions. The goal of conducting related studies, as pointed out by Wang (2006), is to "impact the supply of well-educated workers, advance numerous careers, and provide students with high-quality education and potential for employment" (p. 81) in a world that is constantly changing.

Conclusion

Questions about what types of skills and knowledge should formal GD education include in courses and programmes to best prepare the graduates for professional practice in the future always become a topic of discussion and debate among design educators and industry practitioners (Dziobczenski & Person, 2017; Kang, Chung & Nam, 2015). As noted previously, both parties are important stakeholders in the educational and employability process of graphic designers, but their objectives and missions are fundamentally different (Cheung, 2011). At the same time, the changing nature of the workplace, coupled with changes in the global economy, society, technology, and people's behaviour has diversified the career pathways for graphic designers in the industry (AIGA, 2015b; Dziobczenski et al., 2018), requiring them to possess a broad range of new competencies, including those outside of design disciplines and fields (Davis, 2015; Kiernan & Ledwith, 2014; Nae, 2017). The traditional understanding of design has its limitations in a rapidly changing world and therefore must be re-examined (Davis, 2008).

However, empirical studies on GD discipline (Logan, 2006) and the professional practice of graphic designers (Van der Waarder, 2009) remain limited. Therefore, the competency subdomains and com-

petencies unveiled by this study through a collective of educators and practitioners provide valuable insights on the skills and knowledge in GD graduates required by future employment market.

Overall, the competency subdomains and competencies span a number of different areas, covering some that are typically addressed and those that are newly identified. Good personal traits and ethical awareness were perceived by experts as highly relevant for effective work performance in the GD field. The findings posed immediate challenges to design educators and HEIs in developing the most relevant curricula to help their students to secure a position within a changing professional environment. Apart from focusing on the technical expectations for entry-level employment, design educators may want to prepare students for more senior positions by training them to work in a more integrative and strategic way. New areas of expertise such as project management, teamwork and leadership, and interpersonal skills, should be integrated into different courses in the programmes. Design educators are challenged to introduce these areas to students in the context of design effectively. For industry practitioners and design companies, the findings of this study provide a basic structure or prescribed standards of performance for them in recruiting, selecting, developing, training, and evaluating their teams. In addition, it is hoped that these insights can be used to differentiate professionally trained graphic designers from those informally trained and to enhance the status of GD as a profession.

As technological developments in the GD industry are currently changing many of the job descriptions, there is a greater need for a qualified workforce (Dharavath, 2003). GD educators and practitioners need to work closely to equip the graduates with the competencies required for effective job performance. Such relationship can be established through classroom and curricula activities, intensive design workshops, advisory boards, professional conferences and organizations, design competitions, employment or internship opportunities, student and faculty on-site opportunities, corporate-sponsored research projects, corporate grants, and so on (Roberts, 2007). A new model should be developed to encourage better collaboration between design educators and practitioners.

References

Adu, A. (2015) *Graduate employability: The link between design education and the graphic design industry.* Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Al-Muallem, A., Elzubeir, M., Roberts, C. & Magzoub, M. (2016) Development and Initial Testing of an Instrument for Evaluating Needs and Inferring Readiness of Research Supervisors: A Mixed Methods Approach. *Health Professions Education.* 2 (2), 138–147. Available from: doi: 10.1016/j.hpe.2016.03.001

American Institute of Graphic Design (AIGA) (2010) *AIGA Standards of professional practice.* New York, Aiga, Available from: aiga.org/resources/aiga-standards-of-professional-practice [Accessed: 27th December, 2018]

American Institute of Graphic Arts (AIGA) (2015a) *Designer of 2015 competencies.* New York, AIGA, Available from: http://www.aiga.org/designer-of-2015-competencies/ [Accessed: 27th December 2017]

American Institute of Graphic Arts (AIGA) (2015b) *Designer of 2015 trends*. New York, AIGA, Available from: http://www.aiga.org/designer-of-2015-trends [Accessed: 27th December 2017]

Andrews, C. G. & Allen, J. M. (2002) Utilization of technology-enhanced Delphi techniques. *Workforce Education Forum.* 29 (1), 1–15.

Arbabisarjou, A., Siadat, S. A., Hoveida, R., Shahin, A. & Zamani, B. E. (2016) Managerial competencies for chairpersons: A Delphi study. *International Journal of Humanities and Cultural Studies.* 3(1), 1634–1645.

Berman, D. (2009) *Do Good Design*. California, AIGA & New Riders.

Berman, D. (2013) A dialogue with David Berman. *Cut Out Magazine,* pp. 54–57.

Bridges, A. W. (2013) *Identification of perceived 21st century graphic design skills, content knowledge, and tools needed in an effective university-level graphic design program.* EdD thesis. Gardner-Webb University.

Butler, J. (1995) *The process for effective graphic design curriculum development*. Madison, University of Wisconsin-Madison.

Cheetham, G. & Chivers, G. (1996) Towards a holistic model of numeracy competence. *Jorunal of European Industrial Training.* 20 (5), 20–30. Available from: doi: 10.1108/03090599610119692

Cheetham, G. & Chivers, G. (1998) The reflective (and competent) practitioner: A model of professional competence which seeks to harmonise the reflective practitioner and competence-based approaches. *Journal of European Industrial Training.* 22 (7), 267–276. Available from: doi: 10.1108/03090599810230678

Cheung, B. P. S. (2011) Double 'Blind Spots' of the academia and design industry. In: BODW: *Proceedings of DesignEd Asia Conference 2011, 29-30 November 2011, Hong Kong, China.* Hong Kong, The Hong Kong Polytechnic University.

Cheung, B. P. S. (2016) Professional graphic design knowledge in Hong Kong: From graduate to professional. *Communication Design*. 4 (1–2), 21–40. Available from: doi: 10.1080/20557132.2016.1275476

Chiang, W. S. (2019) Lecturers' understanding of integrating social responsibility dimensions into graphic design curriculum?. *Journal of Education and Social Sciences.* 2 (2), 12–26.

Chiang, W. S., Idris, M. Z. & Chuen, T. W. (2019) Is graphic

design being taken seriously as a profession?. *Journal of Arts and Social Sciences.* 3 (1), 1–9.

Chiang, W. S., Idris, M. Z. & Chuen, T. W. (2018) What makes an undergraduate graphic design education valuable?. *Journal of Education and Social Sciences.* 11 (1), 73–82.

Chiang, W. S., Al-Hudawi, S. H. V., Hamdam, A. R. & Musah, M. B. (2016) Students' understanding of integrating social responsibility dimensions into graphic design curriculum?. *Man in India.* 96 (1-2), 547–566.

Clayton, M. J. (1997) Delphi: A technique to harness expert opinion for critical decision-making tasks in education. *Educational Psychology.* 17 (4), 373–386. Available from: doi: 10.1080/0144341970170401

Cohen, L., Manion, L. & Morrison, K. (2000) *Research methods in education - 5th edition.* New York, Routledge Falmer.

Custer, R. L., Scarcella, J. A. & Stewart, B. R. (1999) The Modified Delphi Technique- A Rotational Modification. *Journal of Career and Technical Education.* 15 (2), 50–58. Available from: doi: 10.21061/jcte.v15i2.702

Davis, M. & Littlejohn, D. (2017) *Accountability for anticipating design outcomes.* New York, AIGA, Available from: https://www.aiga.org/aiga-design-futures/accountability-for-anticipating-design-outcomes/ [Accessed: 12th February 2019]

Davis, M. (2005) Raising the bar for higher education. In: Steven, H. (Ed.) *The education of a graphic designer - 2nd edition.* New York, Allworth Press, pp. 13–18.

Davis, M. (2008) Why do we need doctoral study in design?. *International Journal of Design.* 2 (3), 71–79.

Davis, M. (2015) Interdisciplinarity and the education of the design generalist. In: Steven, H. (Ed.) *The education of a graphic designer - 3rd edition.* New York, Allworth Press, pp. 20–29.

Davis, M. (2017) *Introduction to Design Futures.* New York, AIGA, Available from: https://www.aiga.org/aiga-design-futures/introduction-to-design-futures/ [Accessed: 12th February 2019]

Debbie, G. S. S. (2011) *A nation's visual language: Nation branding and the visual identity of contemporary malaysia.* PhD thesis- partial. Nottingham Trent University.

Delbecq, A. L., VandeVen, A. H. & Gustafson, D. H. (1975) *Group techniques for program planners: A guide to nominal group and Delphi processes.* Glenview, Scott, Foresman & Co.

Dharavath, H. N. (2003) Importance of technical competencies in the graphic communications technology curriculum as perceived by the graphic communications industry and educators. *Journal of Industrial Technology.* 19 (2), 1–7.

Dziobczenski, P. R. N. & Galeotti, A. A. R. (2017) Preparing design students for the market: An initial investigation on the required knowledge and skills for graphic designers in Brazil. *The Design Journal.* 20 (sup1), S1241–S1249. Available from: doi: 10.1080/14606925.2017.1352653

Dziobczenski, P. R. N. & Person, O. (2017) Graphic designer wanted: A document analysis of the described skill set of graphic designers in job advertisements from the United Kingdom. *International Journal of Design.* 11 (2), 41–55.

Dziobczenski, P. R. N., Person, O. & Meriläinen, S. (2018) Designing career paths in graphic design: A document analysis of job advertisements for graphic design positions in Finland. *The Design Journal.* 21 (3), 349–370. Available from: doi: 10.1080/14606925.2018.1444874

Dziobczenski, P. R. N., Person, O., Tonetto, L. M. & Mandelli, R. R. (2018) Requests from companies and requirements for design education in Brazil: Where do they meet?. In: *DRS 2018, Design Research Society International Conference, Catalyst, 25-28 June 2018, Limerick, Ireland.* Limerick, University of Limerick. pp. 2823–2835. Available from: doi: 10.21606/drs.2018.535

Eraut, M. (2007) Early career learning at work and its implications for universities. *Student Learning and University Teaching, British Journal of Educational Psychology (BJEP), Monograph Series.* 11 (4), 113-133.

Frascara, J. (1988) Graphic design : Fine art or social science?. Design Issues. 5 (1), 18–29. Available from: doi: 10.2307/1511556

GDC (2012) *Code of ethics and professional conduct for graphic designers.* Ottawa, GDC. Available from: https://gdc.design/code-of-ethics [Accessed: 1st June, 2021]

Harland, R. (2016) *Graphic Design in urban environments.* London, Bloomsbury Academic.

Hasson, F. & Keeney, S. (2011) Enhancing rigour in the Delphi technique research. *Technological Forecasting and Social Change.* 78 (9), 1695–1704. Available from: doi: 10.1016/j.techfore.2011.04.005

Hasson, F., Keeney, S. & McKenna, H. (2000) Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing.* 32 (4), 1008–1015. Available from: doi: 10.1046/j.1365-2648.2000.t01-1-01567.x

Heller, S. & Vienne, V. (2003) *Citizen designers: Perspectives on design responsibility.* New York. Allworth Press.

Heller, S. (2015) *The education of a graphic designer - 3rd edition.* New York, Allworth Press.

Heller, S. (2005a) The education of a graphic designer. In: *Choice Reviews Online - 2nd edition.* New York, Allworth Press.

Heller, S. (2005b) *Too many grads or too few competencies? The design school dilemma.* New York, Aiga. Available from: www.aiga.org/too-many-grads-or-too-few-competencies-the-design-school-dilemma [Accessed: 27th December, 2017]

Higgins, B. (2008) Program evaluation: Utilizing graduate and employer perception data in determining graduates'job preparedness levels. *Journal of Industrial Technology.* 24 (3).

Hollis, R. (2015) Principles before style: Questions in design history. In: Heller, S. (Ed.) *The education of a graphic designer - 3rd edition.* New York, Allworth Press, pp. 144–146.

Hsieh, S. F., Guan, S. S. & Wu, C. L. (2010) The study on competency of graduating students being major in graphic design. *International Journal of Learning.* 17 (9), 389–402.

International Council of Design (ico-D) (2011) *Best practice paper: Model code of professional conduct for designers.* Montréal, ico-D.

Johnston, L. M., Wiedmann, M., Orta-Ramirez, A., Oliver, H. F., Nightingale, K. K., Moore, C. M., Stevenson, C. D. & Jaykus, L. A. (2014) Identification of Core Competencies for an Undergraduate Food Safety Curriculum Using a Modified Delphi Approach. *Journal of Food Science Education.* 13 (1), 12–21. Available from: doi: 10.1111/1541-4329.12024

Kang, H. J., Chung, K. W. & Nam, K. Y. (2015) A competence model for design managers: A case study of middle managers in Korea. *International Journal of Design.* 9 (2), 109–127.

Keeney, S., Hasson, F. & McKenna, H. (2001) A critical review of Delphi as a research methodology in nursing research. *International Journal of Nursing Studies.* 38, 195–200.

Kiernan, L. & Ledwith, A. (2014) Designers for the of product design graduates in Ireland. The Design Journal. 17 (2), 218–237. Available from: doi: 10.2752/175630614X13915240576022

Lewis, W. P. & Bonollo, E. (2002) An analysis of professional skills in design: Implications for education and research. Design Studies. 23 (4), 385–406. Available from: doi: 10.1016/S0142-694X(02)00003-0

Lim, B. (2015) A discussion on creativity and design education in Singapore and Malaysia. *Journal of Research in Humanities and Social Sciences.* 3 (2), 56–61.

Linstone, H. A. & Turoff, M. (1975) *The Delphi method: Technique and applications.* Reading, Addison-Wesley Educational Publishers, Inc.

Logan, C. D. (2006) Circles of practice: educational and professional graphic design. *Journal of Workplace Learning.* 18 (6), 331–343. Available from: doi: 10.1108/13665620610682062

Marks, A. (2015) A design core for the twenty-first century. In: Heller, S. (Ed.) *The education of a graphic designer - 3rd edition.* New York, Allworth Press, pp. 17–19.

McCollam, P. (2014) Redefine design ethics: Why. *Design and Culture.* 6 (3), 315–325. Available from: doi: 10.2752/175613114X14105155617384

McCoy, K. (1990) Professional design education: An opinion and a proposal. *Design Issues.* 7 (1), 20–22.

McCoy, K. (2003) Good citizenship: Design as a social and political force. In: Heller, S. & Vienne, V. (eds.) *Citizen designers: Perspectives on design responsibility.* New York, Allworth Press, pp. 2–8.

Mullen, P. M. (2003) Delphi: Myths and reality. *Journal of Health Organization and Management.* 17 (1), 37–52. Available from: doi: 10.1108/14777260310469319

Muratovski, G. (2016) *Research for designers: A guide to methods and practice.* California, SAGE Publications Inc.

Nae, H.-J. (2017) An Interdisciplinary Design Education Framework. *The Design Journal.* 20 (sup1), S835–S847. Available from: doi: 10.1080/14606925.2017.1353030

Neves, M. (2017) The future of print design relies on interaction. *The Design Journal.* 20 (sup1), S4087–S4100. Available from: doi: 10.1080/14606925.2017.1352910

Ogbeifun, E., Agwa-Ejon, J., Mbohwa, C. & Pretorius, J. H. C. (2016) The Delphi technique: A credible research methodology. In: *Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management, 8-10 March 2016, Kuala Lumpur, Malaysia.* IEOM Society International. pp. 2004–2009.

Okyere, M. (2017) The graphic design workforce in Ghana: a case study of Asafo, Kumasi. *Communication Design.* 5 (1–2), 183–202. Available from: doi: 10.1080/20557132.2017.1398926

Perkins, S. (2011) *Ethics and Social Responsibility?*. New York, AIGA. Available from: https://www.aiga.org/ethics-and-social-responsibility [Accessed: 27th December, 2018]

Perks, H., Cooper, R. & Jones, C. (2005) Characterizing the role of design in new product development: An empirically derived taxonomy. *Journal of Product Innovation Management.* 22 (2), 111-127. Available from: doi: 10.1111/j.0737-6782.2005.00109.x

Powell, C. (2003) The Delphi Technique: Myths and realities. *Methodological Issues in Nursing Research.* 41 (4), 376–382.

Roberts, J. (2007) The future of academic-industry collaboration. *International Association of Scieties of Design Research.* 1–17.

Stahl, N. N. & Stahl, R. J. (1991) We can agree after all! achieving consensus for a critical thinking component of a gifted program using the delphi technique. *Roeper Review.* 14 (2), 79–88. Available from: doi: 10.1080/02783199109553392

Swanson, G. (2015) Design and knowledge in the university and the "real world ". In: Heller, S. (Ed.) *The education of a graphic designer - 3rd edition.* New York, Allworth Press, pp. 33–43.

United States Bureau of Labour Statistics (2017) *Employment Projections - 2016-26.* BLS: Available from: https://www.bls.gov/news.release/pdf/ecopro.pdf [Accessed: 15th January, 2019]

Valtonen, A. (2005) Six decades – and six different roles for the industrial designer. Available from: https://pdfs.semanticscholar.org/d1d7/479861c9a83c223e35dd5b95c9c26cda5d9c.pdf?_ga=2.215739095.1369317459.1566194522-431526288.1566194522 [Accessed: 18th January , 2018]

Van der Waarder, K. (2009) On graphic design: Listening to the reader?. *Research Group Visual Rhetoric.*

Walker, S. (2017) Research in Graphic Design. *The Design Journal.* 20 (5), 549–559. Available from: doi: 10.1080/14606925.2017.1347416

Wang, S.-Y. (2006) *Identification of the significant competencies in graphic design.* PhD thesis. University of

Missouri-Columbia.
Whiteley, N. (1993) *Design for society.* London, Reaktion Books Ltd.
Wilson, G. D. (2001) Needs assessment: Implications for graphic communications education. *Visual Communications Journal*, 1–6.
Wilson, R. G. (2014) *Curriculum & course design: Preparing graphic design & visual communication students.* MFA thesis- partial. Iowa State University.
wREGA (2012) *Code of professional conduct (COPC)?* Kuala Lumpur. wREGA. Available from: http://www.wrega.org/legal.html [Accessed: 1st June 2021]

Professional paper
http://doi.org/10.24867/JGED-2021-3-025

Design and simulation of an equipment for the rehabilitation of people affected by ACV, starting from the subacute stage

ABSTRACT

Cerebrovascular Accident (CVA) or stroke is a disease that results in paralysis of one side of the body. Physical therapy is generally used as a muscular rehabilitation tool that involves different techniques and exercises. For it to be effective, the process must be accompanied by the constancy and discipline with which the routines are performed, which are frequently limited to the hospital environment, causing an interruption in the development of recovery due to the absence of home mechanisms that facilitate its execution in a safe and complete manner. In Colombia, these aspects are enhanced by intervening factors such as: extensive travel from rural areas to care sites, accessibility to specialized centers, among others. That is why this article provides the proposal of an equipment that contributes to CVA rehabilitation from the subacute stage. The design and operation were developed and simulated through Solidworks 2018 Software, involving a series of exercises for upper and lower limbs considered by physiotherapists as of high importance in the treatment of the disease; it means, they can be executed by the patient under ergonomic and safety conditions.

KEY WORDS
Cerebrovascular accident, stroke, rehabilitation, design, simulation, mechanism

Yuly Jimena González Rodríguez [1]
Geraldine Pulido Morales [1]
Carlos Augusto Toledo Bueno [2]

[1] Universidad Distrital Francisco José de Caldas, Bogotá, Colombia. Industrial Engineering Department Student
[2] Universidad Distrital Francisco José de Caldas, Bogotá, Colombia. Industrial Engineering Department Professor

Corresponding author:
Yuly Jimena González Rodríguez
e-mail:
yjgonzalezr@correo.udistrital.edu.co

First received: 27.4.2021.
Revised: 16.7.2021.
Accepted: 20.7.2021.

Introduction

Cerebrovascular accident (CVA) or stroke is a disease of great concurrence in the world, with a total of 15 million people affected per year, according to data provided by the World Health Organization (WHO) (Puentes Madera, 2014) becoming the second cause of death with approximately 6.2 million deaths per year (corresponding to 10.6% of global mortality) and the third cause of life years lived with disability (Colombian Ministry of Health,2015),of which at least 30% of survivors develop incomplete recovery from functional impairment, and approximately an additional 20% require assistance with activities of daily living (Escudero et al, 2011). In Latin America, CVA has become the second leading cause of mortality with rates of 43.1% per 100,000 inhabitants

(El Espectador Newspaper,2018), which is higher than in countries such as the United States where the figure is around 18% (Newport, 2006) This may be associated with socioeconomic factors, leading countries with higher per capita income to offer more and better-quality stroke prevention measures. Particularly in Colombia, this disease has become the main cause of disability with 250,000 people affected and 45,000 new cases of stroke each year. (El Espectador Newspaper, 2018)

Cerebrovascular accident consists of the generation of tissue necrosis because of inadequate blood supply to a cerebral area, caused either by an obstruction due to the presence of clots or by the rupture of a blood vessel.

When the blood flow decreases, a loss of oxygen and nutrients that the brain receives and needs to carry out its functions is generated. For this reason, health conditions arise, ranging from the difficulty to raise the hands, to speak or the most representative one: the unilateral paralysis of the body. Point on which this work will be based, since only 6% of the affected people reach a total rehabilitation. (Arias ,2009)

Bearing this in mind, it is important to emphasize that the process is based on three stages: acute, subacute, and state. The first one represents a higher risk and patients present loss of consciousness, so they are generally bedridden. It can be interpreted as the time the person remains hospitalized. The subacute stage is the most important because that is the one in which it must be intervene. to recover the motor capacity in the medium and long term because the muscles are tense, and an increase of involuntary reflexes is generated. Finally, there is the period of state, the patient already has a greater degree of mobility and balance. However, it is necessary to continue the established exercise routine to obtain the highest degree of rehabilitation of the patient, and it depends on each specific case. (Arias ,2009)

Currently, the stroke rehabilitation process in the country is supported by physiotherapy, through mechanotherapy equipment (Mayor et al., 2018) and physical means, tries to reduce motor impairment and strengthen the affected nerve signals. There are rehabilitation centers such as Mobility Group that uses various equipment focused on physical rehabilitation, some of these mechanisms are (Mobility Group, n.d.).

Amadeo: passive rehabilitation equipment to stimulate hand mobility and strength.

Lokomat Pro: in charge of stimulating the patient's bone strength and gait performance.

Balance Trainer: it uses visualization and biofeedback resources to promote the recovery of balance and facilitate the patient's bipedalism.

In addition, there are several multimedia apps supported by virtual reality, which contribute to motor and cognitive recovery.

However, physiotherapeutic services offer for this condition is scarcely treated in medical centers with a schedule of 30 therapies on average, given the experience, but they are not enough depending on the case. Thus, to require a greater amount of private physical therapy is not a viable option for users; due to economic factors, displacement, insufficient knowledge in topics such as mechanotherapy, low affordability of equipment to facilitate the execution of the exercise routines established by the physician in a home space where the user can work in a complementary way with the activities performed with the physical therapist, as well as the autonomous work after the personal therapies are finished. All these factors limit the rehabilitation process and decrease the speed and effectiveness of the patient's recovery.

Considering the above, it is expected to design a mechanical equipment that allows people affected by stroke to perform their physical therapies at home, complementing the rehabilitation process in patients who are in post-acute stages. And integrating fundamental exercises that allow the autonomous work of the user and lead to an adequate recovery.

Methodology

The team has been structured along several stages, starting with the information gathering. To this end, the research starts with the characterization of the disease from a general view, covering topics such as: causes, symptoms, sequelae, and treatment. The articles were searched in various databases like Scielo, Dialnet, Scoopus, among others, as well as in the Colombian Ministry of Health and Social Protection website. From the previous search, some found articles contribute to learning about the types of stroke. CVA can be ischemic and hemorrhagic with a probability of occurrence of 80% and 20%, respectively (Arias ,2009), The first is caused by the obstruction of an artery and the second by the rupture of the same. Also, the causes and different stages that the patient goes through during the disease (acute, subacute, and state) mentioned above.

Consequently, the contextualization was made from a quantitative perspective. It started worldwide, then Latin America and finally in Colombia. These data were provided by various bibliographical sources such as scientific articles, news, and designed guidelines by institutions in the country. The Clinical Practice Guide stipulated (Colombian Ministry of Health, 2015) is highlighted because it is useful to understand the impact that stroke has on the nation and its treatment. This topic was necessary to deepen through the investigation of

the various rehabilitation centers in the cities, as well as the affordability of the therapies provided in them, as a continuation of the sessions given directly in the health centers. From this it was possible to identify the weakness that Colombia has regarding the implementation of mechanotherapy, due to its high importance in the rehabilitation of disabling diseases. There are some rehabilitation entities, among them Mobility Group that have several specialized teams. However, these centers present difficulties because they do not have several headquarters, and they are in the big cities. This makes it difficult for people who live in rural areas and increases the costs involved in individual therapies.

After recognizing the context of the disease in Colombia, the investigation of the exercises used in physical therapies corresponding to the rehabilitation of a stroke begins was made by sources such as YouTube, articles and direct communication with health professionals and affected patients. There was a special case of a 86-years-old adult who suffered an episode of stroke in mid-April 2018, caused him hemiplegia (paralysis) of 50% of his bod. It affected his left side and prevented him from sitting, standing, and walking. Around 30 physical therapies were performed during the first months after the stroke, 12 of them performed by the EPS and 18 by private ones, because the patient had not reached a high degree of recovery and required more therapies. It was necessary to complement the process with exercises at home. They consisted of adapting elements or equipment from home such as bands, pulleys and balls and they required the assistance of a family member and the occasional supervision of a physiotherapist. These exercises were mainly aimed at recovering the strength and sensitivity of the patient's upper and lower limbs. And they were performed constantly on a regular basis of 3 or 4 times a week. Thanks to the family support and the adaptation of this equipment at home, an 80% recovery of mobility on the left side was achieved. It is a high number considering his age and the strong impact of the disease. However, it is important to recognize that this is not the case all the time. There are some factors that cause that the patient fails to recover mobility and even become permanently disabled like the patient's displacement to the place where the therapies are performed, the number of therapies assigned are not enough, and the lack of time for supervision and accompaniment by the family members.

The previous collection of theoretical and practical information aims to identify the problems regarding the care of patients, and identify the exercises used throughout the recovery process. Therefore, the classification of these exercises is carried out according to the part of the body that they stimulate: upper limbs, lower limbs, and trunk. The Guide for patients and caregivers of the University Hospital of Gran Canaria (Deniz et al, 2007) was used to select the exercises most used by physiotherapists (after several interviews with them) and in this way reduce the number of exercises to those that are essential for rehabilitation; those that can be carried out by the patient in a home environment; those that correspond to each of the stages of recovery; and those that are adaptable to the equipment to be designed. Also selecting the stages that this project will concentrate: the subacute and the state ones because the patient shows greater mobility.

Mirror therapy and its importance in stroke rehabilitation was also investigated since it improves the motor performance of the therapy through imitation between limbs. According to the article by Cepeda Vega & Gómez Blanco (2011) *Review on the Effectiveness of Mirror Therapy in the Rehabilitation Process of Upper Limbs in Patients with Stroke*, mirror neurons correspond to 20% of the neurons present in the brain and are responsible for perceiving the reflection of movement and activating the contralateral hemisphere of the limb used, increasing the cortico-muscular excitability of the affected area.

Once the exercises were selected in the previous step and to better understand the methodology used for the execution of the movements and to implement them properly in the design of the equipment, videos were recorded showing the performance of the exercises by the members of the project. These were sent to physiotherapists for review and approval, obtaining the following list:

Upper Limbs

- Vertical elbow flexion-extension
- Finger extension
- Crossed elbow flexion-extension

Lower Limbs

- Ankle flexion and extension
- Knee flexion and extension

Based on the previous exercises, the design of the necessary mechanisms and the subsequent simulation of the movements through software was started.

Proposed design for ACV rehabilitation equipment

The selected exercises were investigated and corroborated by specialists in the field, so that they would represent an adequate complement for the patient's recovery after a stroke. The execution of the same is given through mechanisms that adapt to a conventional wheelchair, since it allows the user to move safely and perform the routines assigned in different spaces and

schedules. Following a design that offers independence in each of the movements and promotes their frequency of execution and thus the integrity of the recovery.

Ergonomics is one of the most important fields when designing rehabilitation equipment, as it is responsible for relating products and environments to the needs and limitations of human beings (Aquino,2018) in order to offer attributes of safety, comfort and efficiency (Lascano Herrera, 2011); given the NTC (Colombian Technical Standard) 3955 of 1996: Definiciones y conceptos ergonómicos (Instituto Colombiano de Normas Técnicas y Certficación, 1996), product ergonomics should make use of different principles that allow the satisfaction of customer requirements, offering adequate risk control parallel with efficiency.

Therefore, for the present design, ergonomic parameters are taken into account to provide the patient with appropriate mechanisms for their body, contributing to the preservation of their wellbeing while exercising.

One of the characteristics of the design corresponds to the exercise of both sides of the body, with a view to stimulating the patient's mirror neurons. These neurons are directly related to functions such as learning new skills, imitation, theory of mind and reading intentions (Cepeda Vega & Gómez Blanco, 2011). This process is presented because of the activation of the opposite hemisphere of the body. For this purpose, the equipment has a total of four mechanisms: two of them are in the lower limb area and the others in the upper limb area. This generates the movements corresponding to each of the selected exercises. In such a way that the patient executes them based on the strength of the unaffected body part. The patient follows a series of instructions for use that will be given later and that will be repeated until the number of cycles recommended by the physiotherapist has been completed. It is important to highlight that the mechanisms were designed in such a way that they do not generate discomfort in their use and can be executed simultaneously if authorized by the specialist. In addition, they can be inserted or removed from the wheelchair according to the patient's needs.

The design process began with the development of several sketches about the preliminary ideas of the mechanisms associated with each of the exercises, and their integration into the wheelchair. Then the dimensions and details of operation, and the simulation of the movements using the 3D modeling Solidworks 2018 Software were established. This software also allowed the obtaining of the drawings according to the metrics chosen for each one of them, using the International System of Units in millimeters (mm). The equipment was designed based on the following terms mentioned in NTC 5654 of 2008, which establishes the general requirements for the establishment of an anthropometric database:

Anthropometric data: Measures that correspond to length, height, width, among other dimensions of the human body. (Instituto Colombiano de Normas Técnicas y Certficación, 2008)

Percentile: Statistical distribution in which the elements of an initial sample are assigned to various groups. (Instituto Colombiano de Normas Técnicas y Certficación, 2008)

Taking into account the above definitions, the anthropometric measurements belonging to the 5, 50 and 95 percentiles for men and women between 20 and 59 years of age in the Colombian population for the different areas of the body treated, from which the average of each percentile was calculated for the corresponding measurement (equation 1), obtaining a series of values that were used as a reference interval (lower limit corresponds to the average of the 5 percentile and the upper limit to the average of the 95 percentile), presenting changes in some measurements derived from the construction of the mechanisms, taking into account ergonomic parameters, so as to avoid injuries at the musculoskeletal level and reduce the effort that the patient makes when executing the different movements.

$$\overline{X} = \frac{x_m + x_h}{n} \quad (1)$$

$\overline{X}$ = Average
X_m = Corresponding percentile measurement for women
X_h = Corresponding percentile measurement for men
n = total measures used per calculation

The design of the equipment was based on the current regulations for the application of measurements of a standard wheelchair. These are registered in ISO 7176-5:2008 (International Organization for Standardization, 2008) *(determination of dimensions, mass, and maneuvering space)* and ISO 9999:2007 (International Organization for Standardization, 2007) *(support product for people with disabilities)* The mechanisms were adapted to the parameters given in them and considering studies that cover the anthropometric measurements of the Colombian population in an age range between 20 and 59 years old. (Avila Chaurand, Prado Leon & González Muñoz, 2015) and measures associated with Lower Limbs (Landines Jiménez, Nieves Pimiento & Toledo Buenco, 2019).

The following is a description of the exercises proposed in the equipment and the mechanisms involved, figures corresponding to the planes and the movement described in each one of them are presented:

Upper Limbs

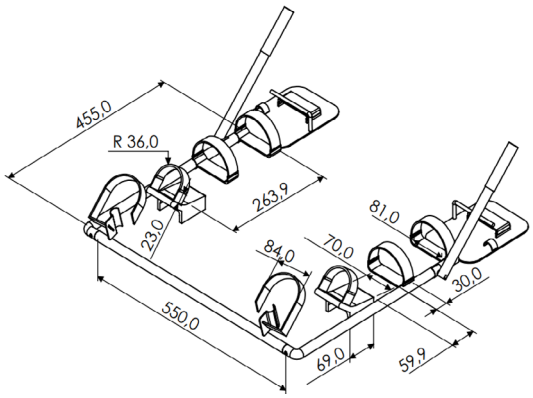
The upper limb area is divided into several exercises that are supported by straps and levers that allow movement

in the magnitude chosen according to research and advice with specialists. Specific measures are also used for each of the exercises proposed, as shown below:

Vertical Elbow Flexion-Extension

The elbow is understood as an essential part for the execution of different important tasks in the daily life of the patient as feeding, cleaning, among others. Which is why the stimulation of the muscles corresponding to this area is vital for an adequate rehabilitation of the upper limbs. Therefore, the implementation of flexion and extension exercises in the proposed design is the main reason for this.

Proposed Design for Flexion-Extension for Vertical Elbow



» **Figure 1:** *Elbow Flexion-Extension Drawing*

To perform the elbow flexion-extension, the equipment is arranged with a total of three upper straps for each arm, located in fingers, wrist, forearm, and arm. This is to provide stability and grip of the patient's limb (Figure 1). There are a few integrated parts that are governed by standard measures regarding the length of the wheelchair, as well as metrics corresponding to the purpose of the exercise, especially in the width. It is necessary to cover the backrest of the chair and at the same time to provide enough space for the location of the arms and thus offer free movement. On the other hand, there are the support straps at specific distances to give grip in specific areas of the extremities.

Operation of vertical Elbow Flexion-Extension Mechanism

The patient should place the hemiplegic arm in supination position (the palm of the hand is facing upwards) and adjust the straps in the places already mentioned in a way that the arm obtains a position of approximately 90°. The same procedure should be performed with the opposite extremity, except strap fingers so that achieved in supination grab the upper rod located on the plate and lift in a range of 0 ° to 90 ° approximately. This will drive the elevation of the affected arm, as it was presented in Figure 2.

» **Figure 2:** *Simulation of Elbow Flexion-Extension Movement*

Ergonomic and anthropometric considerations of vertical Elbow Flexion-Extension

The identification and use of the average values of the anthropometric measurements investigated (Avila Chaurand, Prado Leon & González Muñoz, 2015) as the basis of the equipment and specifically in this exercise, allows us to provide the patient with a comfortable design in accordance with their upper limbs that allows the execution of the movements in an efficient manner, therefore taking into account the different percentiles mentioned, the main measurements calculated and obtained for the construction of the design of the mechanism are presented in Table 1.

Table 1

Average anthropometric measurements of the 5, 50 and 95 percentiles for the Colombian population for vertical elbow flexion-extension exercise

Variable	Equipment (mm)	Percentiles $\bar{x}$ (mm)		
		5	50	95
Forarm length	455	227	239,5	254
Fixed arm width	84	87,4	99,9	112,8
Elbow width	70	58,5	64	70,5
Width of the back	550	397	441	489,5
Flexed arm height	59	40,1	46,7	55

Some of the final measurements of the mechanism may exceed the proposed range due to the construction requirements of the mechanism, converting them into measurements of the equipment itself, however these do not jeopardise the comfort and safety of the user as they are supported by accessories such as straps and supports that provide firmness and the necessary grip.

The arms are initially in extension at an angle of 0° with respect to the height of the armrest so as not to

generate imbalance to the sides or muscular overstrain, ensuring that at the time of executing the exercise an angle with a range of 0° to 60° is reached in the seated position and the extension movement when it returns to its initial point on the armrest; the angle is calculated from the initial goniometric conditions given in the book Goniometría: A tool for the assessment of occupational disabilities (Taboadela, 2007) which are 0° to 150° in decubitus-dorsal position. The location of the armrest also allows the location of the supports in the wrist, mid-forearm and elbow areas at the correct lengths from each other, as these are points that, given the research with physiotherapy specialists and the review of the Guide for patients and carers (Deniz Cáceres et al, 2007), offer stability to the forearm and keep it in a suitable position for exercise, preventing it from becoming dislocated and injured due to the after-effects of the stroke, which can lead to muscle retraction, while respecting the patient's own capacity.

It should be noted that the elbow support is designed to fit the length of the forearm of the Colombian population in the age range of 20 to 59 years, ensuring that it is a safe and stable area for the positioning of the forearm.

The mechanism used allows the patients to elevate the arms in the range that they can do according to their current motor skills. This prevents the patients from overstraining their muscles and allows them to perform the movements safely. This feature is an advantage of the proposed design.

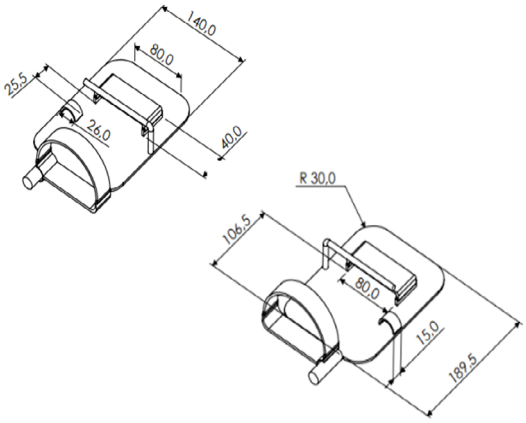
Finger Extension

Motor skills allow to perform most daily activities such as fine motor skills. These skills are affected in cases of stroke. To mitigate those impacts, finger extension exercise will be available to counteract stiffness and "claw hand" syndrome (fingers drawn inward into the hand) (Sentandreau Mañó et al, 2011), contributing to the therapies performed by the specialist.

Proposed Design for Finger Extension

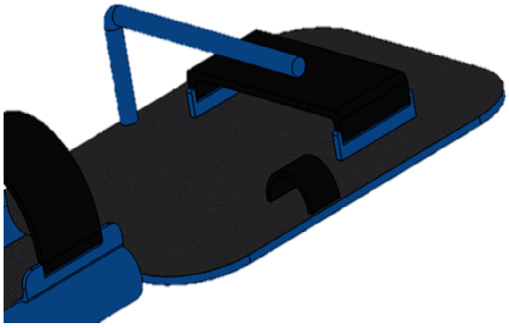
This exercise was designed based on measurements obtained through the investigation of anthropometric studies in the Colombian population regarding the area of the hands (Avila Chaurand, Prado Leon & González Muñoz, 2015), including length, width, and separation between fingers. As it was shown in Figure 3. This is a unique feature of the equipment, so these measurements cannot be found in the regulations of a standard wheelchair, but they were structured to provide safety and comfort to the patient.

By assigning measurements for the mechanism, it was possible to determine the quantity and position of each part involved in the design and operation. At the end, the desired results for the finger extension were obtained.



» **Figure 3:** *Finger Extension Drawing*

Operation of Finger Extension Mechanism



» **Figure 4:** *Extension Finger Mechanism*

To perform this exercise, as shown in Figure 4, the equipment has a plate and two straps, one for each hand and additional supports for each extremity that correspond to those used in elbow flexion-extension. Patients will place their hemiplegic forearm on the supports and the palm of the hand is extended upwards (supination position). With the help of one of the straps located on the plate, four of the fingers of the palm of the affected hand will be held and with the other the thumb, keeping it separated from the others and causing a stretching of them. The opposite hand, since it has movement, does not require this adjustment procedure. Therefore, the mechanism has an upper rod that serves as an impulse base for elbow flexion-extension, as mentioned above. However, it was installed on both sides to facilitate patients' execution of the movements, carrying out an imitation and support process. Likewise, it allows the execution of finger extension independently of the hemiplegic side.

Ergonomic and anthropometric considerations of finger extension exercise

The average main values used as a basis for the finger extension exercise are focused on the hand area,

so length, hand width and finger measurements are taken into account, as shown in Table 2:

Table 2

Average anthropometric measurements of the 5, 50 and 95 percentiles for the Colombian population for finger extension exercise

Variable	Equipment (mm)	Percentiles $\bar{x}$ (mm)		
		5	50	95
Length of hand	189,5	161,5	174,5	189,5
Length of the palm of the hand	106,5	88,5	97,5	106,5
Hand width (plate)	140	73	79,5	86
Finger length	80	73	79,5	86

In this case some measurements coincide with the upper limit of the interval and others like the width of the hand are superior, this is because by including in the plate elements such as straps and supports the amplitude should increase, however the space intended for the positioning of the hand is the necessary, allowing the exercise to be executed with freedom and comfort.

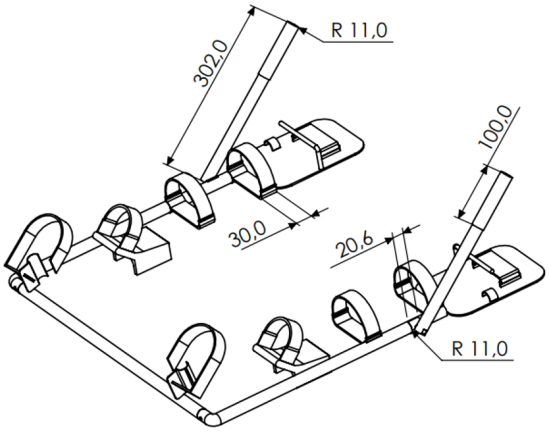
The main plates are designed to keep the thumb at an angle between 0 to 20°, which is the normal interval of abduction, and the other fingers at a position of 0° (Taboadela, 2007), providing through the strap in those areas, the strength to maintain the extension of the fingers when the hand does not possess its own resistance due to the hand-in-claw syndrome caused by spasticity affecting the metacarpophalangeal joints (Monreal González et al, 2016) in addition to the wrist support point, which is equipped with a soft base in order not to cause sores, respecting the freedom of the patient to lift the straps according to their muscle capacity.

Shoulder Flexion

The shoulder is one of the parts most affected after a stroke. This is because since the muscle is in a flaccid state, it is unable to maintain the head of the humerus in the glenoid fossa, causing a subluxation (displacement out of the corresponding cavity). This is usually evident two to three months after the episode and it is considered one of the most common sequelae. Some patients experience pain and have difficulty in performing basic activities. For this reason, it is important to work on the recovery of this area and while the overall rehabilitation process is facilitated.(Murie Fernández et al, 2012).

Proposed Design for Shoulder Extension

Since it makes use of a support lever, this exercise is not supported with specific normative measures as those initially consulted, because it has new mechanisms in this type of chair. Taking as reference anthropometric measurements corresponding to the length of the arm and the angles of elevation of the same becomes necessary. As well as using as a guide the metric for the flexion-extension movement parts, as shown in Figure 5.



» **Figure 5:** *Shoulder Flexion Drawing*

With the given measurements, the inclined lever is arranged so that the patient's arm is extended in the proper position for the exercise and the desired movement is performed.

Operation of Shoulder Flexion Mechanism

» **Figure 6:** *Simulation of Shoulder Flexion Movement*

The device has a lever inclined at 45° with respect to the hand plate corresponding to the upper extremity mechanism. The patient will be able to grasp the handle and raise it to a comfortable amplitude as shown in figure 6. Nevertheless, the design allows a maximum movement of 58.5° due to the angle of inclination is

discounted. This leads to the arm being positioned at an ideal angle of 90° or in the limit case 103.6° to the origin.

The lever is on both arms. This allows the patient to perform the exercise independently of the affected side, thus supporting the mirror therapy. It is important to remember, particularly in this exercise, that the lever can be removed if it is necessary.

Ergonomic and anthropometric considerations of shoulder flexion exercise

The shoulder has three elementary movements which are: elevation (combined flexion movement, abduction and external rotation), external rotation and internal rotation. In this case the team performs the flexion movement which consists of the lifting of the arm in the sagittal plane (Fierro, n.d.) and the return to its initial position on the wheelchair for which some measures shown in Table 3 are taken as reference:

Table 3

Average anthropometric measurements of the 5, 50 and 95 percentiles for the Colombian population for shoulder bending exercise

Variable	Equipment (mm)	Percentiles $\bar{x}$ (mm)		
		5	50	95
Arm length	601,38	674,5	709	750,5
Hand width	100	73	79,5	86

For the execution of the exercise it is not necessary to use straps on the forearm and arm, since holding the inclined lever requires the full extension of the arm and the width of the hand when holding it, so that the user only has to lift it with his unaffected arm to generate movement in both arms.

The arm length protrudes from the measurement range described in Table 3 due to the tilt of the lever, as the 45° angle provides an additional stretch distance that complements the arm length so that it is attainable to the user, and the hand support of the lever allows the patient from his grip ability to have enough amplitude to hold it.

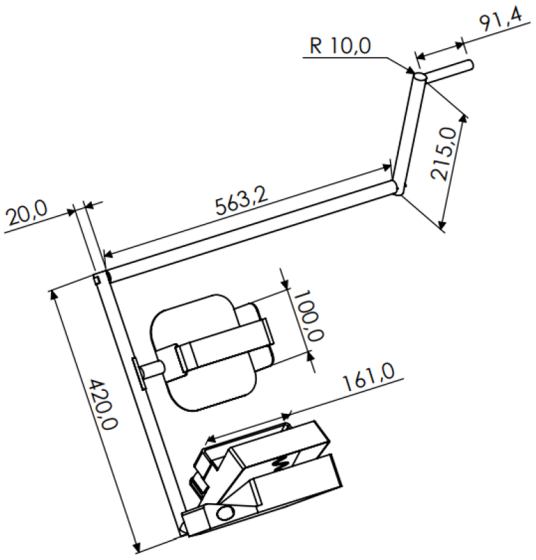
This is a passive-active base exercise, as the user runs it without intensive assistance from the equipment, so the conditions of lever angle and grip width give the patient the freedom of stretching without overexerting the muscles.

Lower Limbs

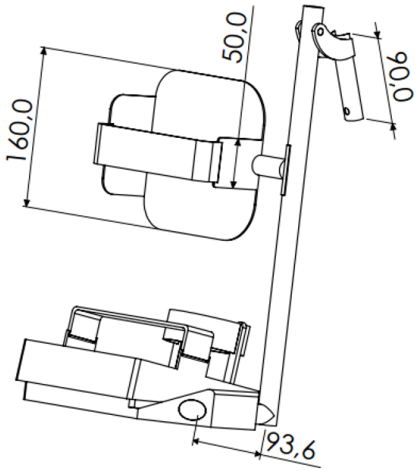
Knee Flexion-Extension

The stimulation of the knee is an essential step for the re-education of the body in the walking activity. Therefore, the execution of flexion-extension of the knee is proposed as one of the main movements of the equipment to encourage full recovery of the patient. (Nogueras et al, 2016).

Proposed Design for Knee Flexion- Extension



» **Figure 7:** *Drawing of Knee Flexion-Extension of the Affected Leg*



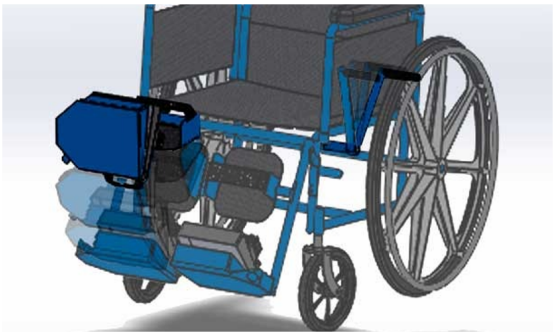
» **Figure 8:** *Drawing of Knee Flexion-Extension of the Non-Affected Leg*

For the design of this exercise, the standard measurements corresponding to the length of the leg, height limit to the armrest, and width were taken as a base.

Nonetheless, some modifications were made to these measurements, for the mechanism to accommodate properly and execute the movement without interfering with the original frame of the wheelchair or causing discomfort to the patient. To get a metric as shown in Figures 7 and 8.

For the straps and grips, special attention is given to the anthropometric measurements already investigated regarding leg width and desired coverage distance for the support, as well as lever support and lever height.

Operation of Knee Flexion-Extension Mechanism



» **Figure 9:** *Simulation of Knee Flexion-Extension Movement*

The equipment reproduces the movement associated with this exercise through the transmission of forces, which find their origin in the main lever located on the unaffected side of the patient. This lever is pushed backwards with the hand, causing the hemiplegic leg support to rise to a maximum angle generating the extension movement. It is important to know that for this case, the range of motion is 69°, since the leg support is inclined at 21°, so that it does not collide with the front tires of the chair. This is accomplished from the starting point to the horizontal position of the limb, making an angle of 90° with the ground.

Knee flexion is produced by bringing the main lever back to its initial position. The bracket descends according to the force applied to the hand by the patient, until it returns to the zero point. This aspect gives patients the freedom to flex and extend in a range of motion that is comfortable for them.

For the unaffected leg, the lifting process is different. It occurs with the force applied to the same limb. The patient should lift the leg and descend so that the exercise is executed, and the hemiplegic part can mimic the movement accordingly as shown in Figure 9.

To secure the patient and corroborate the proper execution of the exercise, the mechanism has two straps. These work as support for the limb, located in the middle of the leg and ankle. At the same time, they collaborate with the flexion and extension of the ankle.

It is important to emphasize that the patient must adjust the straps before performing the movement, to provide the necessary support to the limbs. This step will be performed for both legs.

Ergonomic and anthropometric considerations of flexo-knee extension exercise

The average measurements used as the base of the flexo-knee extension mechanism focus on the lower limb and hip area, since they are necessary for the implementation of the mechanism, those with greater relevance being those observed in Table 4.

Table 4

Average anthropometric measurements of the 5th, 50th and 95th percentiles for the Colombian population for flexo-knee extension exercise

Variable	Equipment (mm)	Percentiles $\bar{x}$ (mm)		
		5	50	95
Hip width	563,1	317,5	361	408,5
Radial height	269	192	234,5	270,5
Popliteal fossa height	420	369	403,5	440

The measurements such as the width of the hip are outside the range raised in the percentiles because the mechanism has a base lever which must protrude from the seat of the chair in order to achieve the mechanical functioning of the same; however this additional length is not intrinsic to the central design of the chair but protrudes from it without affecting the limbs, additionally the angle between thighs and trunk is 90° which allows for a correct postural support point for the patient providing stability to the pelvis (Barrientos, Sánchez & García, 2016) and a length suitable for the extension of the leg, offering a support on the back of it that extends over much of the gastrocnemius muscle, providing firmness to the leg at the time of performing the exercise.

The knee has two fundamental movements, which correspond to flexo-extension and axial rotation, the latter occurs autonomously when flexion is executed. The team focuses the knee mechanism on the first movement, so an initial sitting position is taken into account, which involves a bending of 90° and an extension of 0°.

The design allows a postural cushion to be placed on the seat when using the chair so that it is more comfortable when the movements are executed.

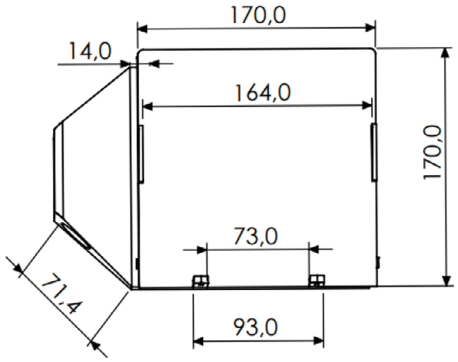
Ankle Flexion-Extension

Among the complications that can occur in stroke, there are some articular affectations at the lower limb level, mainly foot drop, spastic clubfoot, and claw toes due to dystonia (involuntary contraction of the muscles) prevent the patient from having stability in his feet and thus achieve standing upright (Piera, Coulomb & Renard Deniel, 2009).

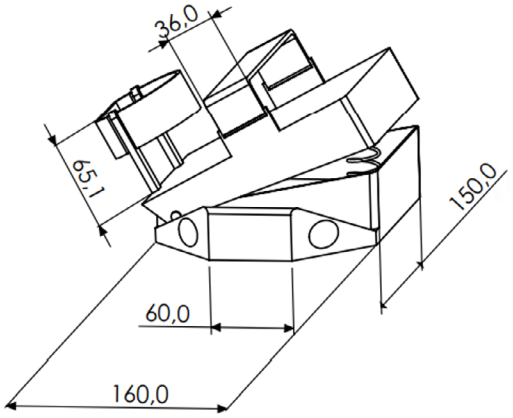
Given these affectations, the need to exercise the foot and ankle safely and with a high degree of independence by means of the equipment arises. This allows flexion and extension by applying force to them. As well as how to maintain a proper position with the help of the straps.

Proposed Design for Ankle Flexion-Extension

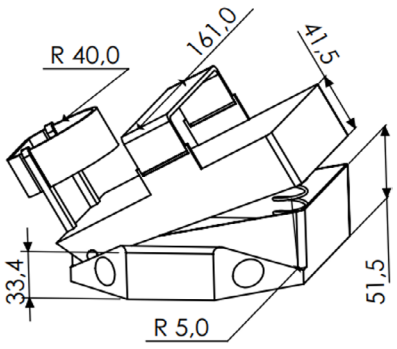
The design of this exercise is based on the anthropometric measurements corresponding to the foot and two fundamental ankle movements which are flexion and extension. In the ankle flexion movement, the maximum angle was identified which is 50° starting from a position of 0°, and a maximum extension movement of 30° which also begins in 0° (Taboadela, 2007)



» **Figure 10:** *Drawing of Ankle Flexion-Extension from Top View*



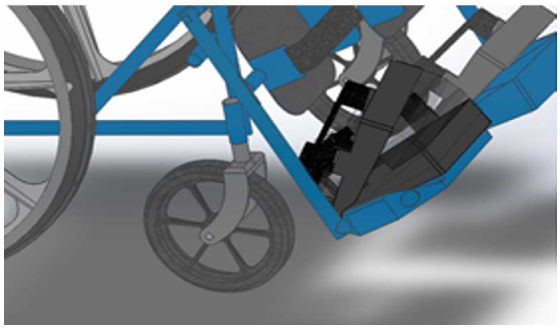
» **Figure 11:** *Drawing of Ankle Flexion-Extension from Lateral View, Part 1*



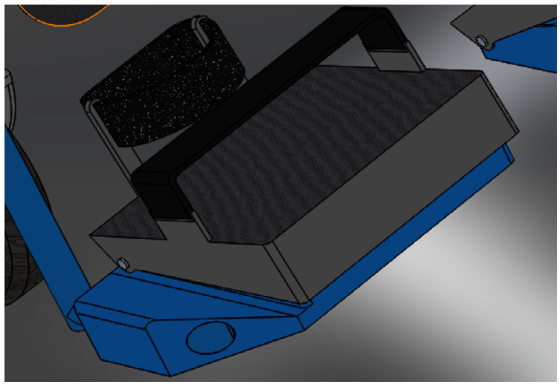
» **Figure 12:** *Drawing of Ankle Flexion-Extension from Lateral View, Part 2*

The foot measurements considered were the width and length, as well as the thickness of the ankle and the appropriate grip height for the execution of flexion and extension. On the other hand, the inclination of the pedals (21°) with respect to the wheelchair frame is defined according to the newly defined metric (Figures 10, 11 and 12). This allows the patient's limbs to be handled safely and comfortably at the angles established in the research for the movement.

Operation of Ankle Flexion-Extension Mechanism



» **Figure 13:** *Simulation of Ankle Flexion-Extension Movement*



» **Figure 14:** *Simulation of Ankle Flexion-Extension Movement*

The mechanism consists of a pedal that replaces the conventional footrest (found in the wheelchair) with one that uses a simple spring inside. This generates the ascent and descent of the pedal according to the force applied (Figure 13). The sole of the patient's foot is placed on the top of the pedal at 20° in dorsiflexion, moving up to 5° with respect to the base of the mechanism. This produces the extension movement as shown in Figure 14.

The equipment has two straps located on the right and left side. These straps are adjusted in the ankle and instep area to the foot acquires the proper position for the execution of the exercise.

Ergonomic and anthropometric considerations of flexo-ankle extension exercise

The area of the flexo-ankle extension mechanism is characterized by being designed with the patient suffering from stroke in mind, so the anthropometric measurements used as a reference are a basis of values modified according to the characteristics of the disease, noting that requirements such as the use of separate footrests to avoid friction between the legs are met, a heel length designed to cover up to the finger area so that the plant is supported, receiving support in the pressure provided by the straps located on the instep and ankle, points that are necessary for the stability of the foot and the proper position for the execution of the exercise since it allows an angle of 90° between the ankle and the base of the pedal when no flexion or extension movements are made.

The width of the footrests is wide because the foot of the patient with stroke tends to lean towards the central area so it is important to maintain enough space for it and not force the movement causing pain, allowing the user and the physiotherapist to decide how much pressure they can receive from the supports.

Taking into account the above, the average measures used as a reference in this mechanism are shown in Table 5:

Table 5

Average anthropometric measurements of the 5, 50 and 95 percentiles for the Colombian population for the ankle flexion-extension exercise

Variable	Equipment (mm)	Percentiles $\bar{x}$ (mm)		
		5	50	95
Foot width	170	86,5	94,5	104,5
Heel length	170	179,5	194	210
Ankle width	62	60,7	67,6	75,2

To conclude the description of the exercises, the different mechanisms described above are integrated to obtain the design shown in Figure 15.

» **Figure 15:** *Integrated Design of the Proposed Equipment for CVA Rehabilitation*

Conclusions

The rehabilitation of a patient who has suffered a stroke depends on several factors. One of the most important is the performance and active participation of physical therapy. This therapy is a fundamental tool for the recovery of skills affected by the disease through the stimulation of muscles in aspects such as strengthening, mobility, among others. For the same reason, the design of equipment that works in environments other than the clinic allows the patient to develop the routines ordered by the professional more frequently. The patient will perform a set of five exercises selected through research and consultation with specialists. Those with the greatest impact on the affected areas were integrated.

The choice of the wheelchair as the basis for this equipment facilitated the insertion of mechanisms that correspond to each of the exercises. These exercises are based on standard metrics, according to the regulations, and the anthropometric measurements of the Colombian population. One of the advantages of this equipment is that any patient in the country can be coupled. The result of this equipment was designed in SolidWorks 2018 Software, which allowed to observe the movement of the mechanisms and the dimensions of each of the elements that make it up.

The advantages of this proposal are on the one hand, it offers patients the opportunity to perform basic rehabilitation exercises in different environments, such as their home. This is so that their recovery process is not interrupted, and they enjoy autonomy due to the ease of execution; just as the physiotherapist is absent. On the other hand, this equipment functions

as a support for the health professional and not as a replacement of the same. It is also added to them, its ergonomic structure so that patients can perform the exercises simultaneously if they and the specialist wish.

The mechanisms were designed to be able to be inserted into a standard wheelchair and accommodate them depending on which side of the body is affected. At the same time, it allows exercising upper and lower limbs in the same equipment. This quality increases its usefulness, since usually the designs intended for specific CVA rehabilitation are focused on a specific area of the body or only one of them can be activated.

The proposed equipment is a proposal that is open to the incorporation of exercises corresponding to occupational therapy (relevant field in CVA rehabilitation) or elements that contribute to the facilitation and execution of the assigned physical therapy.

Acknowledgments

The work done by the physiotherapy Laura Carrillo Garzón and the Engineer Miguel José Pérez González for their guidance in the proper selection of rehabilitation exercises and the management of the software used is acknowledged.

References

Aquino Tapia, D. (2018) *Terapía física en ergonomía laboral*. Undergraduate thesis. Universidad Inca Garcilaso De La Vega.

Arias Cuadrado, Á. (2009) Rehabilitación del ACV: evaluación, pronóstico y tratamiento. *Galicia Clínica*. 70 (3), 25–40.

Avila Chaurand, R., Prado Leon, L. R. & González Muñoz, E. L. (2015) *Dimensiones antropométricas de población latinoamericana.* Guadalajara, Universidad de Guadalajara.

Barrientos, F., Sanchez, J. & Garcia, J. (2016) *Diseño de una silla de ruedas de cambios postulares y posiciones basicas para personas.* Undergraduate thesis. Escuela Superior de Ingeniería Mecánica y Eléctrica.

Cepeda Vega, L. C. & Gómez Blanco, M. A. (2011) Revisión sobre la efectividad de la terapia en espejo en el proceso de rehabilitación de miembros superiores en pacientes con ACV. *Movimiento Científico*. 13 (2), 48-54. Available from: doi: 10.33881/2011-7191.mct.13205

Colombian Ministry of Health (2015) *Guía de práctica clínica de diagnóstico, tratamiento y rehabilitación del episodio agudo de ataque cerebrovascular isquémico, en población mayor de 18 años.* Available from: https://www.iets.org.co/Archivos/46/GPC_ACV_Version_Final_Completa.pdf [Accessed: 2nd March 2020].

Déniz Cáceres, A., Álamo Arce, D., Ruiz Primo, C., Hernández López, M., Gómez García, A., López Fernández, J. & Cubero González, A. (2007) *Guía para Pacientes y Cuidadores: Ejercicios para hacer en casa después de un accidente Cerebrovascular.* Available from: https://terapiaocupacional50.files.wordpress.com/2007/12/ejercicios-para-realizar-en-casa-despues-de-un-acv.pdf [Accessed: 13th February 2020].

El Espectador Newspaper (28 October 2018) Derrame cerebral es la primera causa de discapacidad de adultos en Colombia. *El Espectador Newspaper.* Available from: https://www.elespectador.com/noticias/salud/derrame-cerebral-es-la-primera-causa-de-discapacidad-de-adultos-en-colombia-articulo-820667 [Accessed: 4th March 2020].

Escudero Suárez, J. C., Restrepo Cano, S., Ramirez, E. P., Bedoya, C. L. & Jiménez, I. (2011) Descripción clínica, social, laboral y de la percepción funcional individual en pacientes con ataque cerebrovascular. *Acta Neurológica Colombiana*. 27, 97-105.

Fierro, G. (n.d.) *Movilidad del Hombro*. Available from: https://guidofierro.com/academico/examen-fisico-de-hombro/movilidad-del-hombro/ [Accessed: 1st July 2021]

Instituto Colombiano de Normas Técnicas y Certficación (1996) NTC 3955. *Ergonomía. Definiciones y conceptos ergonómicos.* Bogota, Instituto Colombiano de Normas Técnicas y Certficación.

Instituto Colombiano de Normas Técnicas y Certficación (2008) NTC 5654. *Requisitos Generales para el establecimiento de una base de datos antropométricos.* Bogota, Instituto Colombiano de Normas Técnicas y Certficación.

International Organization for Standardization (2007) ISO 9999:2007. *Assistive products for persons with disability — Classification and terminology.* Geneva, International Organization for Standardization.

International Organization for Standardization (2008) ISO 7176-5:2008. *Wheelchairs — Part 5: Determination of dimensions, mass and manoeuvring space.* Geneva, International Organization for Standardization.

Landines Jiménez, K., Nieves Pimiento, N. & Toledo Bueno, C. A. (2019) Simulation of forces applied to the human femur: Analysis of finite elements. *Revista vínculos.* 16 (1), 73–81. Available from: doi: 10.14483/2322939X.15575.

Lascano Herrera, P. (2011) *Diseño y construcción de una máquina de gimnasio para realizar rutinas de ejercicios con fuerza relativa.* Undergraduate thesis. Pontificia Universidad Católica del Ecuador Sede Ambato.

Mayor, J. J. V., Jiménez, N. J. V., Hoyos, G. P. A. & Bravo, E. F. C. (2018) Sistema de Biofeedback para Rehabilitación de Marcha Asistida por un Exoesqueleto. *Revista Ingeniería Biomédica.* 12 (24), 50-59, Available from: doi: 10.24050/19099762.n24.2018.713

Mobility Group (n.d.) *Equipos Mobility Group.* Available from: http://www.mobilitygroup.co/mobility/page/equipos [Accessed: 9th March 2020].
Monreal González. R., Gómez Hernández. D., Faedo Castro, E. & Osinaga Egüez, G. (2016) Modificación simplificada de la técnica de Zancolli para la corrección de la garra cubital. *Revista Iberoamericana de Cirugía de la Mano.* 44 (2), 91–96. Available from: doi: 10.1016/j.ricma.2016.08.006.
Murie Fernández, M., Carmona Iragui, M., Gnanakumar, V., Meyer, M., Foley, N. & Teasell, R. (2012) Hombro doloroso hemipléjico en pacientes con ictus: Causas y manejo. *Neurologia*. 27 (4), 234–244. Available from: doi: 10.1016/j.nrl.2011.02.010.
Newport, R. (2006) Ventajas de la rehabilitación asistida mediante robot en la recuperación de las funciones motriz y visuoespacial en pacientes en fase de recuperación de un accidente cerebrovascular. *Revista Española de Geriatría y Gerontología*. 41, 66-73.
Nogueras, A. M., Arenillas, C. L., Rodríguez, O. F., Iglesias, B. C. & Sánchez, S. C. (2016) Fases de la marcha humana,Human walking phases. *Revista Iberoamericana de fisioterapia y kinesiología.* 2 (1), 44–49.
Piera, J. B., Coulomb, Y. & Renard Deniel, S. (2009) Pie del adulto hemipléjico por accidente cerebrovascular. *EMC - Podología.* 11 (2), 1–12. Available from: doi: 10.1016/s1762-827x(09)70688-1.
Puentes Madera, C. (2014) Epidemiología de las enfermedades cerebrovasculares de origen extracraneal, Epidemiology of the cerebrovascular diseases of extracranial origin. *Revista Cubana de Angiología y Cirugía Vascular*. 15 (2), 66–74.
Sentandreau Mañó, T., Salom Terrádez, J., Tomás, J., Meléndez Moral, J., de la Fuente Fernández, T. & Comapany José, C. (2011) Electroestimulación en el tratamiento de la mano hemipléjica espástica después de un ictus: estudio aleatorizado. *Medicina Clínica.* 137 (7), 297–301. Available from: doi: 10.1016/j.medcli.2010.10.024
Taboadela, C. H. (2007) *Goniometría: Una herramienta para la evaluación de las incapacidades laborales.* Buenos Aires, Asociart Art.

Review paper
http://doi.org/10.24867/JGED-2021-3-039

Kiev ex-libris school as a xylography traditions keeper in printmaking of modern Ukraine

ABSTRACT

The article is dedicated to Kiev ex-libris school role (EL) in modern Ukrainian printmaking. The loss process by a bookplate of utilitarian, applied functions and its transformation into an independent work of art, collectors' object of interest with an appreciated art value is described. The ex-libris schools formed in the first quarter of the 21st century are emphasized, the main trends of the bookplate development predominant centers are defined (Kiev, Lvov, Odessa, Luhansk). Printmaking techniques, typical for a particular ex-libris school, are marked. Kiev bookplate school, as one of the leading centers for the classical xylography traditions preservation, is underlined. The most significant masters, working in these techniques, are presented, the technological process evolution is indicated and its main reasons are emphasized. The problem of opposition between the old and new in the art of printmaking is touched upon by example of classical techniques and gathering momentum computer graphics (CGA) coexistence.

KEY WORDS
Printmaking, xylography, chalcography, ex-libris, woof cut, lino cut

Julia Romanenkova [1]
Anna Paliychuk [1]
Vadym Mykhalchuk [2]

[1] Kiev Municipal Academy of Circus and Performing Arts, Department of Music Art, Kiev, Ukraine
[2] National Academy of Culture and Arts Management, Department of Culturology and Art-Management, Kiev, Ukraine

Corresponding author:
Julia Romanenkova
e-mail:
20romanenkova20@gmail.com

First received: 20.6.2021.
Revised: 18.7.2021.
Accepted: 23.7.2021.

Introduction

On the cusp of the XX and XXI centuries there are trends that are truly considered to be the main ones for these art types emerging in the field of Ukrainian printmaking and graphic design. The first trend lies in a rather rapid movement towards a clear line erasing between the graphic arts and graphic design, the second one – in old traditions and new developments in graphic arts, primarily is in printmaking, that far from always lead to the organic synthesis formation, but more often – to the displacement of one by another. In both cases the computer graphic arts (CGA) popularization in recent years have become the most pronounced reason, to the arsenal of which the artists increasingly resort to, abandoning the means of printmaking classical techniques artistic expression. And this is most clearly manifested in the ex-libris field that has received a new step of its development since the 1990s. If for a very long time from the moment of its appearance and existence, beginning in the 16th century, the bookplate had been performing a strictly applied function, then in the last few decades it rapidly went beyond the utilitarian role and acquired aesthetic qualities. This process ended with the fact the bookplate almost completely separated from the book nature, having lost its dependence on it and turned into an independent work of art. In all countries of the world, where ex-libris has an existence history and demand, this process took place, but the name is slightly different in chronological framework and time. In the USA and Asian countries, the bookplate follows a separate evolutionary path, not having such popularity there and not being so in demand among collectors and graphic arts admires, as in the countries of Europe

and the post-Soviet ones. In Europe, back in 1966 year, FISAE, the International Federation of Bookplate Lovers, was founded, whose history began in Germany, as well as the history of the bookplate itself, the first samples of which were also published in Germany, Austria, Belgium, Great Britain, the Netherlands, Poland, Russia, Slovakia, the Czech Republic, Ukraine can be called to be among the countries, where the bookplate is especially popular, that is expressed in the presence there a large number of highly professional masters, many collectors, specialized museums, often holding competitions and exhibitions (Romanenkova, 2015a) . In each of the countries the competition and exhibition process has its own specificities: the competitions that have become constant or at least frequent, somewhere dominate (Ruse ex-libris competition in 2019, 2020, the one in Sint-Niklaas, 2019, ex-libris competition in Bristol in 2020, etc. are among the recent examples), specialized publications dedicated to the bookplate are printed somewhere (Belgium – «Graphia», Portugal – «Encyclopaedia Bio-Bibliographical of the Art of the Contemporary Ex-Libris», etc.), some of the countries can boast of relevant societies apart FISAE ((Great Britain – «Society of Wood Engravers», «Royal Society of Painter-Printmakers»; Germany – «Deutschen Exlibris-Gesellschaft»; Italy – «Associazione Italiana Ex Libris»; Russia – «Russian MSC Ex-libris Association (Moscow book-lovers community)», St. Petersburg «Ex-libris Collectors Club»; Ukraine – «Ukrainian Ex-libris Club»; France – «Association Française pour la Connaissance de l'Ex Libris», «L'Ex Li bris Française», etc)) (Romanenkova, Bratus & Kuzmenko, 2021). Competitions organizing and societies creating process has been continuous for the last half of the century, but in Ukraine it has intensified, having given an opportunity to talk about modern Ukrainian ex-libris school birth and a new landmark in its history only since the early 1990s, when the country gained independence. It was from this time the artists overcame the «Iron Curtain», became mobile, got the opportunity to join the international artistic process and become the part of world art field.

Literature review

Precisely because of a rather clear divide between the classic bookplate history and its modern «art biography», the ex-libris problem bibliography consists of two research categories – ex-libris works until the 1990s and ones on Ukraine purely modern bookplate from the period of its independence. The first category is represented mainly by unrelated works on the ex-libris history certain aspects from the 16th century: these are researches by N. Belichko, Y. Berdychevsky (Berdychevsky, 1977), P. Vyunik, the Ukrainian ex-libris club chairman P. Nesterenko (Nesterenko, 2002; Nesterenko, 2020), O. Lamonova. Only one dissertation was defended, dedicated to Ukraine bookplate from its appearance to the first half of the XX century, the author of which was the same P. Nesterenko, who later published several monographies on the same topic. This testifies to the lack of complex scientific studies on Ukrainian ex-libris topic, and there are still known to be prospects for research work.

In very rare cases it is possible to find in the literature sources that would illustrate the bookplate creating techniques (Nesterenko, 2002) – there are very few practicing artists among the theoretical developments authors who are well-versed in the technological process intricacies (Kamenetskaya, 2019).

The second sources category covers Ukraine ex-libris of the last three decades. In the bulk of works there are also the ones dedicated to individuals; developments on certain topical issues of this period bookplate evolution: articles by J. Kamenetskaya, the author of still the only dissertation on modern Ukrainian bookplate (Kamenetskaya, 2019), V. Mikhalchuk (Mikhalchuk, 2014a; Mikhalchuk, 2014b), J. Romanenkova (Romanenkova, 1999a; Romanenkova, 1999b; Romanenkova, 2003; Romanenkova, 2015a; Romanenkova, 2015b; Romanenkova et al., 2021; Romanenkova, 2021), T. Safonova (Safonova, 2011), V. Tupik (Tupik, 2017); exhibitions reviews, individual collections characteristics. Ukrainian researchers' publications about country bookplate, that go beyond it, should be especially pointed out, – this type of prints popularization has become one of the clearest trends in modern graphic art in Ukraine. There are many foreign critics and collectors, and sometimes the artists themselves, Ukrainian ex-librists' works connoisseurs in the bibliography and sources of authorship. Patrons appeared, both in Ukraine and in the other countries, supporting talented masters' development, sponsoring exhibitions, publishing books, catalogs (it is S. Brodovich in Ukraine, whose publishing house has issued a lot of monographic studies about modern Ukrainian masters of a bookplate, for outside the country – a Belgian L. Van Den Briele, an Italian M. de Philippis, a Portuguese A. M. da Mota Miranda, etc.)

Bookplate schools in modern art of Ukraine

In Ukraine bookplate wide diversity of the last three decades there is a tendency to detach several main centers of its development and popularization that allows us to speak of the independent schools formation, represented by interesting, highly professional masters (Romanenkova, 2021). Each of these centers has its own stylistic features, characteristics collection that allows one or another artist to be referred to a particular school, based not only on the geographical aspect. It is not infrequent that certain deserving masters can be highlighted, outside the school, because noticing the ex-librists among the artists range alongside them gets failure, but they

themselves are so significant and remarkable for the ex-libris history that become independent elements in the picture. One example is Konstantin Kalinovich – a master from Luhansk, where the school as such was not formed, however, this artist became one of the most significant for understanding the modern Ukrainian bookplate and printmaking in general, having a huge competitive and exhibition experience, being in demand among the most famous collectors, having become recognizable for the unique author's style and technique. Andrey Khvorost, representing Kirovograd, Miroslav Korol from Ivano-Frankovsk, Orest Krivoruchko from Chernovtsy, Vasiliy Leonenko from Chernigov, Boris Romanov from Severodonetsk, Vladimir Lomaka from Sumy, the famous Odessa resident David Bekker, and others stand out as well. It would be inappropriate to make any mention of them, because their works are peculiar to general picture of the development and compilation of Ukraine bookplate general stylistics at the turn of the XXI century.

However, one may truly talk of independent ex-libris schools in several art centers of Ukraine, each of which is marked by a large number of ex-librists. First of all, this is the Lvov school (with its main representatives in the person of Sergey Ivanov, Sergey Khrapov, Oleg Denisenko, Oleg Andreev, Igor Bodnar, Artem Bulka, Valeriy Demyanishin, Boris Drobotyuk, Olga Fedoruk, Orest Gelitovich, Igor Yanovich, Yaroslav Kachmar, Yuriy Kokh, Yevgeniy Kozanevich, and others), the Kharkov school (represented by Vadim Aleksandrov, Viktor Igumentsev, Alla Khmel, and others) and, of course, the capital's art center – Kiev bookplate school. Printmaking techniques, where ex-librises are created, can be called one of the most significant features that determine the characteristics of a particular school. Each school has its certain preferences, they might most be clearly defined in the Lvov school – chalcography techniques have been dominating there for a long time, at most it is either pure etching, which is used without mixing with other techniques (C3), or several techniques complex combinations, whose tooling is synthesized in one sheet: etching, mezzotint, aquatint, soft ground etching (C3C5C7). Lvov bookplates colour range is often quite monochrome and black-and-white compositions are not infrequent. Although masterfully executed multicolour etchings can be also found (V. Demyanishin).

Kiev ex-libris school at the cusp of the XX and XXI centuries

But the capital school is characterized by its technical preferences polyvector nature. Tamara Balenko, Sergey and Anatoly Burtovoy, Arkady Faktorovich, Victor Romanenkov, Yuriy Galitsyn, Stanislav Gavrilyuk, Konstantin Kozlovsky, Vasiliy Lopata, Nikolay Stratilat, Aleksandr Savich, the Kharuk brothers, Vladimir Taran, the Pugachevsky creative dynasty, Konstantin Antioukhin, Yulia Kamenetskaya, Ruslan Agirba, Aleksandr Savich, Ruslan Vigovsky – only a small part of the masters, representing Kiev school in the international art field. There are black-and-white and colour xylography, lino cut, lithography, congreve printing (blind), etching, mezzotint, aquatint, soft ground etching, copper and steel engraving. Many artists have a shot at both xylography and chalcography techniques. Bent for computer graphic arts, as one of the more and more popular in the bookplate creation, has become the main trend in the last few years. It is notable this choice is made most often by the representatives of the artists' young generation (Y. Kamenetskaya), more rarely – by the middle one (R. Vigovsky) (Figure 1), while the older generation adheres to classical prints techniques, not replacing them with CGA tooling.

» **Figure 1:** *Vigovsky R. EL Armand Bohr. CGA. 2009*

This speaks not only of certain tendencies in techniques choice within Kiev ex-libris school, but also gives emphasis to another trend – the bookplate gradation probability from book's elements, book graphic arts' segments to the field of computer design, that increasingly crosses critics' lips. However, it will be yet only the one of the events development options if, as time progressed, the CGA more and more displaces academic prints with all the variety of its techniques. Unfortunately, such a possibility exists because academic classical techniques with all their complexity are less often accessible to artists, young masters infrequently are able to use them professionally. Moreover, the professional art education degradation level does not aid classical techniques preservation and development. Another reason for the academic printmaking techniques risk of disappearance is the economic aspect, i.e. materials' high price. Lino

cut remains among the still more accessible one, lithography, as before, is a rather expensive pleasure, therefore, it cannot be referred to the favorites in the list of techniques used by bookplate masters. Wood cut might typify the evolution of technological aspect in xylography. Quite a lot of stages have passed from the academic interpretation to the technique modern reading, both the materials and icon obtaining process peculiarities have being changed. If initially only certain wood types were used to create engravings, using the xylography technique (woof cut is more often known for its solidity), then in recent decades it is increasingly possible to meet with engravings on cardboard, organic glass, and plastic. Various plastic types have been used for a long time as the most popular and accostable synthetic substitute for wood, which is expensive due to its naturalness. It can be of different thickness, up to very thin, not much thicker than heavy paper. Coated with black colour and used as a base, it allows to attain a soft, flowing stroke. Artists as well use organic glass to create bookplates (e.g., N. Stratilat often resorts to it), which cannot be considered an equivalent substitute for wood due to a different structure that does not give the velvety stroke that is possible, when engraving is created on a wood base. Cardboard, which is also used as a basis for printing form creating, cannot be absolutely accepted as wooden boards substitute; working on it leads to the destruction of xylographic sheet true creating process understanding. While copying, the cardboard gets soaked quite quickly, absorbing the paint, goes through a limited circulation and absolutely cannot give a clear, finely-honed picture, a stroke of pinpoint precision, which is possible for wood or plastic. Due to its availability, cardboard is often used in higher educational establishments, when students-artists learn the technology ropes. But this is particular what should not be allowed – getting used to bad material from the very beginning leads to the fact the artist too often allows himself afterwards a compromise in technology, artificially simplifying printing form creating process that results in a loss of icon quality. Wood cut, especially on hard boxwood, is far from being possible for every master, even physically. This job requires a well-positioned, firm hand and a perfect eye.

Plastic has become an equivalent but cheaper synthetic substitute for wooden forms. It is often used by modern ex-librists of the Kiev school. Quality materials have always been a significant formula for future work success. The masters of the old school, classical training still operate today according to this principle. Unfortunately, the younger generation inclines to simplify the process, that compromise the quality of works. In addition to the basis, on which the printed form for xylography is created, paper has always been of no small importance – of certain solidity, textures, shade. Today, despite the widest range of paper types used for printmaking, more and more masters, who try to preserve the xylography classic traditions making paper by hand, appear. The Kiev artist of Georgian origin R. Agirba began to use handmade paper, following the Luhansk graphic artist K. Kalinovich, known in many world countries for his author's books, created completely by hand. He, like many masters representing Kiev bookplate school, tries his hand at both xylography and chalcography techniques. His earlier ex-librises were created mainly in the xylography technique – they were plastic engravings, both black-and-white and in several boards, polychrome (Figure 2). The works created in this particular technique have brought the fame and prestigious awards to the master at more than 20 international exhibitions. Recent years the master has given preference to etching, making reprints on handmade paper, thus, demonstrating one of the main Kiev school trends – artists' experiments in different techniques, as opposed to, for example, Lvov ones, who traditionally prefer chalcography.

» **Figure 2:** *Agirba R. EL Klaus Thoms. X6/6. 1996*

Many Kiev ex-librists such as, for instance, V. Romanenkov, V. Taran, Y. Galitsyn, A. Savich, V. Lopata, and others work in the same technique. Sometimes xylography tooling and congreve (blind stamping) synthesis experiments can be observed, in some cases gilding comes into use, i.e. xylography is enriched with printmaking methods and means (V. Romanenkov). The representatives' of the Pugachevsky dynasty creative works are characteristic by many criteria, they are definitely can be called the xylography traditions keepers in the modern Kiev ex-libris. Arkady and Gennady Pugachevskys – father and son – are two generations representatives, each of which has become a quintessence kind of the most remarkable features inherent in both generations. This is manifested both in the technique choice and images character, which each of the masters stylizes in his own way.

Their creative biographies are quite demonstrative in one more aspect: they are «unofficial» prominent representatives, one can say – of Ukraine graphic arts underground layer, in particular, of the Kiev school. Neither Arkady nor Gennady are included in the official art community – they are not members of the National Union of Artists of Ukraine, do not have awards received within the country, in actual fact do not exhibit within Ukraine. Arkady Pugachevsky (who died in 2021), like his son, had only a few personal exhibitions in Ukraine in the early 1990s. (1990 – Lvov, 1991, 1992, 1995 – Kiev), i.e. at the beginning of Ukrainian bookplate renaissance, and it was he who was one of this process originators. But at the same time he was a member of «Deutschen Exlibris-Gesellschaft» (Germany) and «Society of Wood Engravers» (Great Britain), winner of grand prix, first prizes, special prizes at dozens of international exhibitions in Belgium (1993, 1995, 1996, 1997, 1999), Poland (1992, 1993, 1994, 1995, 1996, 1997, 2001, 2003), Italy (1994), Japan (1998), Lithuania (1993, 1994), the USA (2001, 2006). Master's works posthumous exhibition was also being prepared outside his own country – his talent connoisseurs in China were the first who decided to pay respect to the artist memory.

Gennady Pugachevsky is also not included in the artists community recognized in his country, well-treated by the authorities from art. He did not even receive a specialized education, having left the institute's walls without completing his studies. But it did not prevent him (rather – helped forward) from receiving the Associate Fellowship of the Royal Society of Painter-Printmakers (Great Britain) status and became the Society of Wood Engravers (Great Britain) member. The master received the most significant awards at prestigious exhibitions and bookplates and applied graphics competitions in Spain (1992), Lithuania (1993, 1997), the Netherlands (1993, 1995, 1997, 1998), Poland (1993, 1994, 1995, 1996, 2001), Denmark (1994), the USA (2001, 2006), France (1997), Italy (1994). It is thanks primarily to A. and G. Pugachevsky the Ukrainian bookplate was recognized outside the country. They are long-time participants in the FISAE congresses, it was they who organized bookplate first international exhibition-competitions in Ukraine (1993, 1994) in the cooperation with the president and several members of the Ukrainian ex-libris club founded in the 1990s.

Arkady Pugachevsky had been working in plastic engraving technique for many years and his hobby was not limited to ex-libris. His sheets could be either black-and-white, with the stylization maximum degree, conventionality and closeness to the sign system, or coloured. And if the artist's prints can be rather large sized (Figure 3), then the ex-libris was usually quite chamber (Figure 4). Pugachevsky's Sr. graphics' technique can be called an etalon – his engraving tool gave a birth to compositions of amazing polish, the highest level of professionalism.

» **Figure 3:** *Pugachevsky A. «Collection». X6. 2002*

» **Figure 4:** *Pugachevsky A. EL (P.) Van Os. X6/12. 1993*

Gennady Pugachevsky, in spite of the fact he studied xylography under his father, has a different images style, more delicate, fragile, light, but his compositions performance level is high as well, if not to say it more strikes with scrupulousness and pinpoint precision. Greater sensitivity to the spirit of the time is the main thing that distinguishes Gennady's work from his father's artistic searches. There is not only ex-libris in the technique of plastic engraving but web-design, computer graphics, water colours, logo, graphic design, etc. in the artist's arsenal as well. Belonging to a younger generation has its impact. It should be noted the ex-libris itself, as well as the sheet of his prints (Figure 5), was also created by Gennady in the permanent xylography technique, more often in colour. Moreover, its polychromy sometimes

reaches uniqueness – some compositions are printed from 15-17 boards. At the same time, the combination process during printing becomes almost inimitable and requires the highest level of technical skill (Figure 6). G. Pugachevsky's imagery is more sophisticated, refined, his oeuvre includes much more non-objective compositions, stylization reaches a high standard while there is a fine sense of humor in object compositions, although stylized, but more meaningful and close to naturalist representation in his father's works.

Conclusions

Kiev modern ex-libris school can rightly be considered one of the most universal: on the one hand, its representatives are trying to extend their technological experiments range to the maximum, working in techniques of both chalcography and xylography, having a tolerant attitude to innovations, trying their hand at computer graphic arts, synthesizing classical techniques tooling. But, on the other hand, it is the Kiev masters, who might make the most tangible contribution today to xylography academic, classical techniques preserving process, resorting to xylography to create a bookplate. And it is precisely because of the Kiev ex-libris school representatives Ukrainian wood and plastics engraving is known far beyond the borders of the country, which became possible because of the intense exhibition and competition artists' activity, their mobility and readiness for the Ukrainian ex-libris presentation at a creative event of any level.

References

Berdychevsky, J. (1977) *The art of ex libris [Mystetstvo exlibrisa].* Kiev, Advertising.

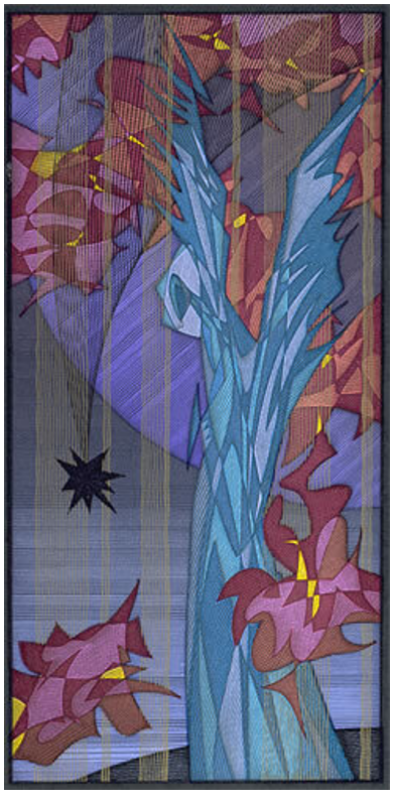
Kamenetskaya, Y. (2019) Contemporary Ukrainian ex-libris in the collection of the Frederikshavn Art Museum. *East European Scientific Journal.* 5 (45), 4-7.

Mikhalchuk, V. (2014b) Ex-libris as an object of collecting: the experience of modern Ukraine. *Scientific aspect.* 2, 92-10.

Mikhalchuk, V. (2014a) The main trends in the actualization of ex-libris on the contemporary world art market. *Bulletin of the HDADM.* 3, 70-75.

Nesterenko, P. (2002). Ukrainian Ex-Libris of the XVI-XX centuries. Conceptual foundations of development and periodization. *Materials for Ukrainian Art History.* 1, 163-169.

Nesterenko, P. (2020) Ex-libris as an research on the history of Ukrainian culture, a complex of spiritual achievements of society. *Art-platform.* 2, 162-179.



» **Figure 5:** *Pugachevsky G. "Grief of blue Angel". X6. 1999*

» **Figure 6:** *Pugachevsky G. EL Dirk Hart. X6/6. 1995*

Romanenkova, J. (1999a) Graphic image of philosophy and mythology. *Encyclopaedia Bio- Bibliographical of the Art of the Contemporary Ex-Libris.* 24, 101-112.
Romanenkova, J. (1999b) By colour words about white ex-libris. *Encyclopaedia Bio-Bibliographical of the Art of the Contemporary Ex-Libris.* 24, 153-162.
Romanenkova, J. (2021) Bookplate in the artistic culture of Ukraine at the turn of the XX and XXI centuries. *Text. Book. Book publishing.* 25, 122-143.
Romanenkova, J., Bratus, I. & Kuzmenko, H. (2021) Ukrainian Ex Libris at the End of the 20th Century and the beginning of the 21st century as an instrument of the intercultural dialogue. *Agathos*. 12 (22), 125-136.
Romanenkova, J., Bratus, I., Mikhalchuk, V. & Gunka, A. (2021) Lvov ex-libris school as the traditions keeper of the intaglio printing techniques in the Ukrainian graphic arts at the turn of the XXth and XXIth centuries. *Revista inclusiones.* 8, 321-331.
Romanenkova, Y. (2003) Ukrainian ex-libris of the last third of the XX century in the worldcontext: the main evolutionary phases. In: *V scientific and technical conference "AVIA2003", 23-25 April 2003, Kiev, Ukraine.* Kiev, NAU. pp. 102-105.
Romanenkova, Y. (2015a) Ex-libris as a method of taste forming in modern art space. In: *Fourth Kazan art history Readings, 19-20 November 2015, Kazan, Tatarstan.* Kazan, Zaman. pp. 67-69.
Romanenkova, Y. (2015b) Ukrainian ex-libris on the international arena of contemporary graphic arts. *Art Criticism of Ukraine.* 15, 111-118.
Safonova T. (2011) Informativeness of the Ex-Libris: aesthetic aspects. *Herald of the National Academy of Culture and Arts Management.* 1, 79-84.
Tupik, V. (2017) The role of Ukrainian ex-libris artists in shaping of the competitiveness of Ukrainian graphic arts in the international arena. *Young scientist.* 5 (45), 80–83.