TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
ARCHITECTURE | ARCHITEKTURA

11-A/2015

RENATA A. GÓRSKA*

GRAPHICACY CAPABILITY AS A FACTOR ENHANCING SUCCESS IN ENGINEERING DISCIPLINES

ROZPOZNAWANIE OBRAZÓW GRAFICZNYCH JAKO CZYNNIK DECYDUJĄCY O SUKCESIE W DYSCYPLINACH INŻYNIERSKICH

Abstract

The analysis of the "state of art" of the research work conducted in Poland and its relation to the foreign research results within the field of "graphicacy" in context of engineering education and gaining success in engineering disciplines is the aim of this work. The pilot study conducted in this respect concerns, in the first stage, the definition of these elements of engineering education which are crucial for graphical subjects to design syllabuses in order to achieve expected learning outcomes. A framework for graphicacy curricula development will be defined while taking into account the element of lifelong learning. In conclusion, the direction of the further research work will be formulated in order to enhance graphicacy capability among engineering students and within engineering studies.

Keywords: graphicacy research, visual literacy, spatial skills development, curriculum planning for engineering studies

Streszczenie

Praca dotyczy badań prowadzonych w zakresie dziedziny o nazwie *graphicacy* (ang.), czyli umiejętności rozpoznawania i rozumienia obrazów graficznych przez studiujących na kierunkach inżynierskich. Pilotażowe badania w przedmiotowym zakresie dotyczą w pierwszym etapie zdefiniowania tych elementów kształcenia w zakresie grafiki, które stanowią istotny czynnik w studiowaniu na tego typu kierunkach, a następnie planowania zawartości sylabusów dla przedmiotów graficznych w takim celu, by uzyskać spodziewane efekty kształcenia. Ostatecznie wskazane zostaną te elementy kształcenia, które mogą być wykorzystane w procesie tzw. kształcenia ustawicznego (ang. *lifelong learning*). W podsumowaniu wytyczono kierunek dalszych badań.

Słowa kluczowe: badania umiejętności rozpoznawania obrazów graficznych, rozpoznawanie obrazów wizualnych, kształcenie wyobraźni przestrzennej, sylabusy dla przedmiotów graficznych

* Ph.D. Eng. Renata A. Górska, Descriptive Geometry, Technical Drawing and Engineering Graphics Section, Faculty of Architecture, Cracow University of Technology; rgorska@pk.edu.pl.

1. Introduction

Research conducted in the field of perception and recognition of graphic images and their correct interpretation have been carried out by psychologists since many years [15]. Just as literacy, numeracy or articulacy play a very important role in the development process of each individual, graphicacy provides the students of engineering specialties the tool that is helpful for gaining success in their professional life as designers and practicing engineers [10, 11, 14]. Individual predisposition to understand and to be able to recognize, and to correctly interpret graphic images has become a major trait required from the future engineer. The theory of perception, image analysis, research on the signal detection and/or interpretation, recognition of the so-called optical illusions have always been the domain of developmental psychology [12]. It must be mentioned here that the Gestalt theory, developed by German scientists: Max Wertheimer, Wolfgang Kohler and Kurt Kofka, plays a crucial role in engineering design. To give an example, let us cite Żakowska [16] who applied some of the Gestalt laws of grouping into the theory of visualization in road design. These laws were: Law of proximity, Law of similarity, Law of closure, Law of common fate, Law of continuity, Law of good Gestalt, Law of Past Experience. Żakowska [16] explained how road perception influences road safety.

Systematic research on graphicacy will result in creating a framework for the subjects that belongs to a group which has been defined as the "visual science" in [3]. The term of "visual science" has never been introduced into the official classification list of research areas specified by the Polish Ministry of Science and Higher Education. The group of subjects within the graphics area at technical universities includes the following subjects: Descriptive Geometry, Computer Graphics, Fundamentals of Computer Aided Design, Technical Drawing, Design Visualization and Rendering, BIM Technology, Visualization in Construction and Road Design. While creating a framework for programs addressing the needs of engineering students it is extremely important to find a common denominator for the research, which is the development of the skills in recognition of graphic images. The subject has been known to researchers in many countries [2, 3, 5, 15] and is also known within the Polish environment [9, 16]. However, in Poland, the research field of the "graphicacy" area has been primarily recognized only by the psychologists.

The aim of this part of research starts with a systematic analysis of literature in the Polish and foreign environment. The research goals (RGs) for the analysis conducted here are as follows:

- to recognize the levels of awareness of the importance of visual literacy development in the frame of engineering studies (RG1),
- to develop relative curricula for the engineering subjects, including the factor of "visual science" (RG2),
- to recognize the possibility of taking a continuum approach in graphicacy development for lifelong learning (RG3).

In recent years, major changes have been introduced into the system of higher education in the common European Higher Education Area [7]. The National Qualifications Framework (NFQ) has assumed that the national curricula will develop and/or reconstruct the curricula by defining and taking into account the so called "learning outcomes". The development of curricula at engineering studies resulted in limitation of teaching hours assigned to particular subjects and to re-arrangement of the so-called "graphical" subjects into common modules.

When creating new programs for "graphical subjects" and their contents, the educators should take into account the element of a potential development of graphicacy capability. It is important that the future engineers should be able to correctly recognize graphic images, to interpret two-dimensional plans and views in a three-dimensional space, to be able to correctly orient the spatial objects and perform manipulation on the three-dimensional objects (e.g. rotation, mirror imaging). Thus, when planning on the content of the lectures at engineering studies, the educators must undertake a systematic and intentional action, which complies with the research results in the field of spatial perception and recognition of graphical images that have been conducted both in foreign countries by Danos and Norman [5, 6] as well as in Poland [9].

2. Graphicacy Research and Taxonomy

Visual literacy, i.e. graphicacy, has been recognized as an everyday life skill and has been identified as the factor playing a substantial role in engineering. Graphicacy, as a personal ability or skills to communicate through visual images, has become the point of interest of many educators around the world.

Bertoline [3], when defining a newly emerging discipline of "visual science", argued that eighty per cent of our sensory input comes from the visual system. He stated: "There is a tremendous amount of information that is associated with producing good graphics. Colour theory, projection theory, cognitive visualization, and geometry are a few examples of what is needed to plan and to produce graphics. Graphics is used to communicate and store information, solve problems, and affect the senses". He justifies using the term "visual science" instead of "graphic science" as the word "graphic", by definition, is limited only to text and pictures, while the word "visual" encompasses not only these two elements, but it is also a broader term including anything that is seen or able to be seen by the eye. Illustration 1 shows a modified diagram of the fields of research that should be included in the discipline of a *visual science*. The original diagram was published by Bertoline in [3] while some new elements have been added by the author to complete the chart by taking into account more broader insight of visual science as graphicacy, the elements such as n-dimensional geometry or kinematic features. Illustration 2 presents the graphical elements included in graphicacy research after Aldrich and Sheppard [1] and examined by Danos and Norman [6].

Norman and Seery [11] have recognized the complex relationship between designing and modelling processes, where graphicacy plays the key role for representation of a design project (Illustration 3 after [11]). Danos and Norman [6] developed the new taxonomy for graphicacy, the taxonomy which was originally based on the Fry taxonomy [8] and which has been newly designed, completely remodelled, and updated from a cross-circular textbook analysis in order to become adequately tailored related to the requirements of graphicacy recognition and research. Illustration 4 presents all seven of the graphics categories (after [6]).

At engineering studies, it is important that the students present good levels in graphicacy capability and visualization skills. Numerous research works conducted at the turn of our age showed that many freshmen level students, who were just enrolled into engineering studies, presented low levels of these skills. Sorby and Górska [14] theorized and proved that the special graphics courses in 3-D visualization skills, which were developed for engineering undergraduate studies and addressed to the so called "low visualisers", had a significant impact on the improvements of visualization/graphicacy skills. As a measure of these skills, various testing instruments have been used, among others, there was MRT (Mental Rotations Test), Purdue Spatial Visualization Test: Rotations, Mental Cutting Test and Differential Aptitude Test: Space Relations Tests. These tests have been administered to the students prior to and after the course. A special textbook on spatial visualization skills training that covered various methods of 3-D object representations on a 2-D picture plane and simultaneously trained the ability to recognize 3-D object based on their 2-D views has been developed by Sorby [13]. In conclusion, after taking the special courses within which the earlier mentioned textbook has been used as a manual, it was possible to state that the stress put on the hand-made sketching and drawing tended to improve spatial skills more than the courses that stressed computer–aided design (CAD) methods.

RG1: The awareness levels of the importance of visual literacy (=graphicacy) development in the frame of engineering studies.

Illustration 3 (after Norman and Seery [11]) presents the complicated role that graphicacy plays to bridge designing with modelling. The model can be supplemented with a rendered visualization of a designed structure. The methods used for visualization today include a wide range of methods starting from preparation of sketchy drawings, creating 2-D and 3-D wireframe representations, using realistic, conceptual or shaded styles for model representation, and finally executing the advanced renderings with proper light, background, materials and textures application.

Graphicacy development within the selected graphical courses that have been specified at engineering studies aims at gaining certain educational goals and learning outcomes, which have been described by Danos et al. [5]. As specified in [5], the commonality in graphicacy outcomes between the two case studies taken from two different countries (the US and Poland) can be summarized as the abilities to: sketch engineering objects in freehand mode, create 2-D geometry, create 3-D solids, create mesh and surface computer geometry, visualize 3-D solid computer models, add dimensions, create section views, generate engineering 2-D drawings from computer models, analyse 3-D computer models.

RG2: Development of relative curricula for the engineering subjects, including the factor of “visual science” and “graphicacy capability” among the students.

The case study presented here will summarize the effects obtained in the three graphical courses: Descriptive Geometry (DG), Technical Drawing (TD), Fundamentals of Civil Engineering (FoCE) and Computer Aided Design (CAD) at two faculties of CUT: Architecture and Civil Engineering.

Nowadays, a concurrent design work performed as a teamwork activity and executed in a common space, which is e.g. a cloud, and it requires application of BIM (Building Information Modelling) technology. Today, the educators must focus on introduction of new technologies and redefinition of the course curricula (=syllabuses) in such a way that the engineering students were trained in new CAD technologies in which graphicacy plays a substantial role.

Within our DG course, the students are mastering the skills and the knowledge on the basics of representation methods used in engineering and they are also trained to be able to provide a freehand sketching of the designed ideas. DG course is the only one where the students do not utilize CAD techniques.

Technical Drawing (TD) course provides the students with a systematic knowledge of the standards used for conveying design ideas in a form of standardized symbols and conventions used within architectural and structural design, they master the conventions how can be added dimensions, provide the “Bill of materials” both for the r.c. (Reinforced concrete) and metal structures, the schedules of doors and windows, etc. The course utilizes AutoCAD software, which is the most common tool used by the designers in Poland today.

Fundamentals of Civil Engineering Course (FoCE) utilizes ArchiCAD software, which has originally been designed as the BIM tool. Starting from a 3-D model construction, each student is able to define an individual type of a wall applied to a structure by defining its attributes to be a composite structure. A composite structure is constructed out of multiple leafs (=skins) and it is possible not only to define thicknesses for each leaf, but also to assign a material from it is constructed and its physical properties. A complete design project provides physical information on the Energy Performance of a building, which complies with the requirements set up by the 2002/91/EC Directive. The tools for creating a 3-D visualization in a form of, either a perspective, or an axonometric view, automatic sectioning, detailing and zones calculation are helpful in a design process.

In frame of Faculty of Architecture, the students who are coming to our university as the “Erasmus” participants, who sign into one of two courses in CAD01 or/and CAD2. In frame of the CAD2 course, they have a chance, among the others, to master another BIM software, which is Revit. There is a high interest shown from the students’ side to master this modelling software, even though they are the beginners in the BIM modelling.

In all four courses described above, graphicacy, which is the potential of our students to be able to recognize 3-D objects, to make a 3-D model of a designed structure, to create a technical documentation, is being developed by using various methods and tools. Surprising is the fact that our engineering students tend sometimes to forget the acquired piece of knowledge after they have had completed a specific course. As a good example can serve here dimensioning. Each year it turns out that, after completing a Technical drawing (TD) course and subsequently getting enrolled into the FoCE course, our students forget the application rules they learned in TD.

RG3: Recognition of the possibility of taking a continuum approach in graphicacy development for lifelong learning.

The principle of lifelong learning was adopted as one of the canons of education in the united Europe. Created EQF (European Qualifications Framework − EQF), and on the basis of national qualifications frameworks, where basic qualifications names are defined as follows: a) bachelor and/or an engineer as the Level I of education, b) Master of Science as the level II, c) a Ph.D. – as the level III of education. Presented here results of the research work relate to two qualification levels: I and II. As it has been proved above, a critical factor in studying technical contents is the ability to correctly read and interpret graphic images. For the engineering studies, it is important that the students were able to create designed structures in the mind, and then to be able to construct a computerized model both of the structure and the environment, to create technical documentation in accordance with the recommendations of the Polish and European standards. Obviously, by gaining the learning outcome there is no guarantee that the students preserve the taught material in their minds if they do not continue learning and practicing. Our educational experience provides numerous examples were the students, after having completed one course, seem to "forget" the basics in the following graphic course. To give the simplest example, we may focus our attention on adding dimensions to a designed structure. Therefore, it should be emphasized that technical education requires continuous strategies over the entire course of engineering studies. The elements, which characterize continuity of technical education are: a) the ability to correctly represent a design project with the use of simplified or conventional symbols and the ability to understand and to "read" a symbolic graphic notation, which is equivalent to ability to graphic images recognition. In accordance with the recommendation of the European Parliament and of the Council of 23 April 2008, and for the establishment of the European Qualifications Framework for lifelong learning life, every qualification in higher education is characterized by: a) learning outcomes and b) the workload level for each subject that is expressed in ECTS credits.

6. Conclusions

This paper provides an overview of the current state of the research conducted in the field of graphicacy with the use of newly developed taxonomy by Danos [6]. As graphicacy term has been neither used nor utilized by the educators in Poland, there is the need to define the relation between graphicacy development and general education, but also its relation to engineering education. The author has analysed the elements of her earlier research on the spatial skills in context of graphicacy ability development, and new educational policy that has been introduced in the common European Higher Education Area. The new policy assumes that the universities are given the opportunity to shape individual programs for particular subjects while only specific learning outcomes are expected. In consequence, new syllabuses for graphic subjects have been developed, and these include the factor of graphicacy development and enhancing spatial skills among engineering students. The analysis provided in this paper shows that apart from imagination, graphicacy plays a vital role as a deciding factor on gaining success in engineering studies. The subjects of descriptive geometry, technical drawing, engineering graphics and CAD techniques (visual science) are the fields where the graphicacy skills can be developed, and thus there should be more general guidelines developed for these areas. Further research will be conducted on the graphicacy development and its importance in the engineering education.

References

[1] Aldrich F., Sheppard L., *Graphicacy, the fourth 'R'?*, Primary Science Review, 64, 2000, 8-11.

[2] Barr R.E., Juricic D., Krueger T.J., *The Role of Graphics and Modeling in Concurrent Engineering Environment*, EDGD 58 (3), 1994, 12-21.

[3] Bertoline G.R., *Visual science: an emerging discipline*, Journal for Geometry and Graphics, Vol. 2, (2), 1998, 181-187.

[4] *Autonomia programowa uczelni*, eds. E. Chmielewska, Z. Marciniak, A. Kraśniewski, MNiSzW, Warszawa 2010.

[5] Danos X., Barr R.E., Górska R.A., Norman E., *Curriculum planning for the development of graphicacy capability: three case studies from Europe and the USA*, EJEE, Vol. 39, No. 6, http://dx.doi.org/10.1080/03043797.2014.899324, 2014, 666-684.

[6] Danos X., Norman E., *The Development of a New Taxonomy for Graphicacy*, Laughborough University, https://www.researchgate.net/publication/48353152, 2008, 69-84.

[7] EQF_EHEA 05 a, *European Qualification Framework for Educational Higher Education Area*, Bergen 2005, http://www.ond.vlaanderen.be/hogeronderwijs/bologna/documents/QF-EHEA-May2005.pdf, 2005.

[8] Fry E., *Graphical Literacy*, cited in Journal of Reading, No. 24 (5), 1974, 383-390.

[9] Górska R.A., *Spatial Imagination – an Overview of the Longitudinal Research at Cracow University of Technology*, Journal for Geometry and Graphics, Vol. 9 (2), 2005, 201-208.

[10] Leopold C., Sorby S.A. and Górska R.A., *International Experiences in Developing the Spatial Visualization Abilities of Engineering Students*, Journal for Geometry and Graphics, Vol. 5 (1), 2001, 81-91.

[11] Norman E., Seery N., *Online Conferencing: Designing and Innovation*, [In:] *Graphicacy and Modelling: IDATER 2010*, edited by E. Norman and N. Seery, 5-15. Leicestershire, UK: Design Education Group, Laughborough University, 2011.

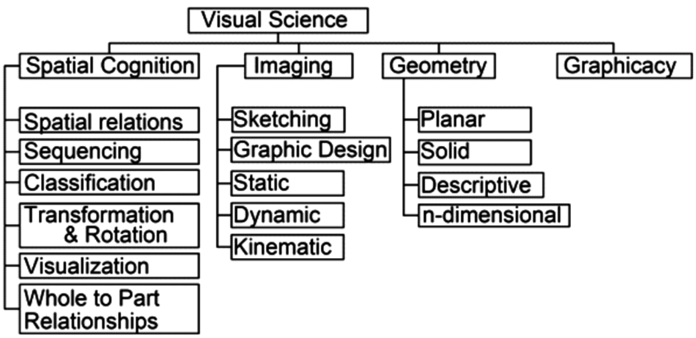
[12] Rużyczka A., *Sensory Impression, Signal Detection and Optic Illusion*. Proc. 21st conf. Geometry Graphics Computer, Gdańsk–Sopot 2014, Gliwice 2014.

[13] Sorby S.A., Manner K.J., Baartmans B.J., *3-D Visualization for Engineering Graphics*, Upper Saddle River, Prentice Hall, New York 1998.

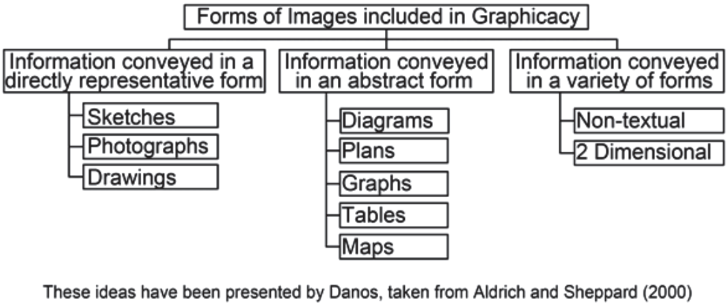
[14] Sorby S.A., Górska R.A., *The Effect of Various Courses and Teaching Methods on the Improvement of Spatial Ability*, Proc. 8th ICEDGDG, Austin, Texas 1998, 252-256.

[15] Wilmot D., *Graphicacy as a Form of Communication*, South African Geographical Journal (Special Issue June) 81(2), 1999, 91-95.

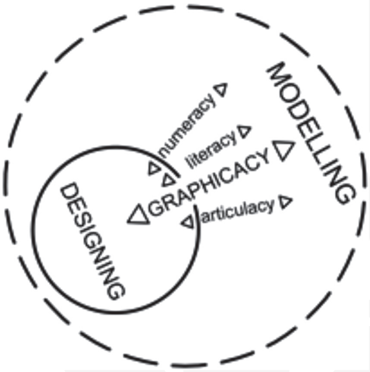
[16] Żakowska L., *Wizualizacja w projektowaniu dróg: Aspekty bezpieczeństwa i estetyki*, Wyd. Politechniki Krakowskiej, Zeszyty Naukowe Architektura Nr 44, Kraków 2001.



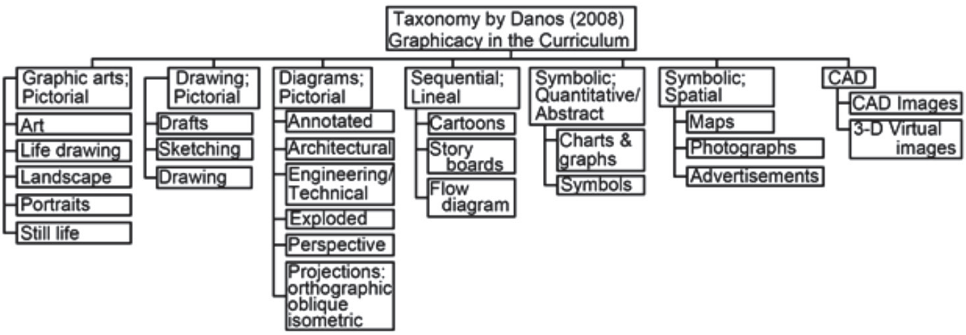
Ill. 1. Modified Visual Science Subject Matter – the ideas represented by Górska and taken after [3] and [6]



Ill. 2. Some of the graphic forms included in graphicacy – illustration taken from [6] and [1]



Ill. 3. Illustration of the complex relationship that graphicacy plays within designing and modeling – illustration taken from [11]



Ill. 4. Examples on how Design and Technology (DT) contributes to teaching and learning graphicacy taxonomy taken from [6]