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The experience of applying a method to develop the use of color theory

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Abstract

As is suggested by experience, young people beginning their technical studies in higher education know little about color theory, their knowledge is not systematized and the majority are incapable of applying what they learnt from a number of sources. In this article a method will be introduced which aims at systematizing what secondary-school schoolchildren learn about color theory and allows them to apply the methods of IT consciously. Part of the methodological research is to elaborate an interactive, multimedia color theory educational software and apply it in Short Color Courses. It is recommended that applying our elaborated chromatics teaching software should be integrated into teaching IT in the secondary schools, so as to teach schoolchildren how to handle colours, as well as lay down the foundations of IT sciences such as computer graphics and digital image processing. We are summarizing the experience and results gained in the application of the method in schools.

Keywords: color theory, educational software, skills development

MSC: 97D40, 97U50

1. Introduction

"Colour is life; for a world without colours appears to us as dead." (Johannes Itten)

In education (in all types of school), from the aspect of the of color theory, our main task is to prepare young people for a world dominated by colors, colorful, natural and built surroundings, colorful objects, pictures, posters and printed documents as well as color films, etc. Color theory is taught and learnt and applied creatively in teaching several subjects (such as drawing, physics, chemistry, biology, art history, information technology) in primary and secondary schools based on the National Curriculum (see [15]), on which professional training is built at a later stage.

We have experienced that young people can hardly use their knowledge of color theory that might involve several problems in learning and mastering certain professions (see [16]). This deficiency can especially be observed in technical higher education, more specifically in the field of architectural planning and product design, computer graphics and digital picture processing, where creating a harmony of colors is part of daily work. One reason for the deficiencies is that the knowledge gained from various fields is not arranged into a unified whole and does not turn into a consciously used means. The deficiencies can be experienced at several levels: lack of basic knowledge, lack of knowledge arranged in a unified way, lack of color defining, color-distinguishing skills, sensing colors, aesthetic sense as well as a low level of adapting the knowledge available.

A developing method needs to be elaborated and used to motivate the schoolchildren attending secondary-schools so as to be able to prepare young people for the requirements of higher education.In our well-elaborated method, we suggest that teaching colour theory should be organically and well-concertedly linked to informatics, applying means of IT and teaching IT. By applying our method, IT sciences such as computer graphics and picture processing can be made more popular, and their foundations can be laid down. In addition, the programme mentioned above must exploit inherent potentials of computers to represent and manage colors.The schoolchildren should be enabled to get to know concepts, abbreviations such as RGB and master their colour theory backgrounds.

2. Potentials and means of developing the knowledge and skills of color theory

A research project aimed at developing the knowledge and skills of color theory has been going on at the Faculty of Engineering of Debrecen University for years.

The research is aimed at developing applicable means as well as applying them under control, where the efficiency of methods can be measured. Part of the research is to survey students' problem-solving skills in terms of color theory by measuring the conscious application of the color theory, and color perception regarding the ([16]). The test revealed that the overwhelming majority of students did not actually have the competencies prescribed by the National Curriculum ([15]), so students do need developing courses. They preferably have to attend the courses in the secondary-school because developing color theory is rather difficult with university students due to their age.

To achieve that aim a method has been developed for secondary schools that focuses on the importance of color theory and applicability within the Short Color Course of a few hours, which offers rich experience while pointing out how they are related to each other. It also highlights the tools needed to develop the skills needed for their creative work such as color sensitivity, and their ability to define and distinguish colors.

The unique nature of the training method is especially obvious in defining the themes of processing, assembling the means facilitating mastering knowledge as well as in the way it is applied.

3. Historical review

The fact that colors are important in our life is also borne out by the fact that a great number of scientists, physicists, doctors, painters, poets and philosophers have done research into colors and the secrets of colors.

The origin of the complex science dealing with colors goes back to ancient times. Chinese, Egyptians, Greek canons and scientific views raised the question: what is color? How can or does it have to be used and interpreted? In the Middle-Ages, branches of science were separate so optics had a chance to become partially independent.

It was the Renaissance Period when color emerged as an independent issue. Questions of science and art related to colors soon merged, but it required a person who could examine the origin of colors as a scientist, and one who was an artist at the same time was curious about the context that was so definitive in practice (see [8]).

Personalities from different scientific fields doing research into color included Pithagorasz, Platon, Arisztotelész, Grosseteste, Alberti, Leonardo da Vinci, Forsius, Kirschner, Newton, Mayer, Lambert, Goethe, Scopenhauer, Hegel, Runge, Young, Chevreul, Grassmann, Maxwell, Delacroix, Helmholtz, Bezold, Seurat, Ostwald, Rood, Hofler, Munsell, Itten, Nemcsics, etc.
Leonardo summarized his research related to this field in Trattato della pittura.
Newton began to research colors during his research into optics and light optics. He summarizes the results of his research in Principia (1685) and Opticae (1704).

One of the least-known features of the life of Goethe, the prince of poets, is his research into colors and his comprehensive conclusions that he drew from art practice, chemistry, physiology and psychology (see [7]). Although the poet is mostly celebrated for his poems all over the world, it was not his literary work that he considered lasting. He said towards the end of his life: *"I do not think much of what I created as a poet. Many a great poet lived in my era, even greater before and many more will live after me. But the fact that I am the only one to know the truth in the complex field of color theory in this century is something that I am proud of and even makes me feel I am above others."*

The main work of Ostwald, the chemist, is Die Farbenlehre. The subjects of the five volumes published are: the color theory of mathematics, physics, chemistry, physiology and psychology. Hemholtz, a doctor and mathematician elaborated the theory of additive and subtractive mixing of colors. In the second half of the XIX. century, Bezold studied chromatopsy, color appearance, Rood and Hofler focused on sensed scene. However, the ultimate and most important features of color theory emerged in XX century physics, physiology and psychology.

It would be time-consuming to list the research and practice fields but it includes all visual arts, the world of symbols and language, ergonomics, sciences and several industries. The results of tests related to the system of colors and color collections used today were summarized by Billmeyer, and it is reported by the annotation bibliography AIC (Associatione Internationale de la Couleur) containing 435 publications published in 1986 ([14]). The Color-teaching special group called Associatione Internationale de la Couleur (SGCE) teaches color theory and develops methods in education. Szín-Vonal a professional working party, focuses on color theory in primary, secondary and higher education.

4. Short Color Course

The method of Short Color Courseaimed at developing knowledge and skills of color theory was applied in seven secondary-schools in Debrecen between 2013-2015 involving 240 schoolchildren. The lessons were held 17 times in normal and irregular lessons, as well as study circles and special school activities. An occasion meant 4×45 minutes.

It was already suggested by Comenius in his "Didactica Magna" that things should be presented by sensing and experiencing, reasoning, through our own considerations and by accounting for others' opinions. We suggest that processing the material be based on experience, whereby practice precedes summarizing and classifying theory.

5. The color theory themes of Short Color Courses

In this section we present a proposed order of processing the knowledge belonging to different disciplines and considered relevant and useful by ourselves.

Studying the main characteristics of color (hue, saturation, brightness) and classifying colors should be started with color-comparison, color-matching tasks, as our experience suggests that students are rather uncertain in distinguishing hues, dark-light, and saturated-unsaturated color values. This should be followed by the practice of color blending tasks, blending paint colors and light colors. Based on the experiential results of these tasks, the teaching material of optics and light physics is summarized (electromagnetic radiation and light, refraction of light, reflection of light, blending light colors), as well as the explanation of the physiology of visual sensing, the process of colored vision, light source, light reflection, the operation of the eyes and brain. This is to be followed by defining the color-concepts of various sciences (see [2, 3, 5, 6, 10, 13, 19]).

As colors are influenced by their environment, that is the colors surrounding them, we study their interactions and misleading behaviour. For instance, one color should seem two, two colors should seem identical, the color-changing effect of background is to be studied in terms of hue, saturation and brightness, different backgrounds - identical color pattern identical backgrounds-different color patterns (see [1, 14]). Colors look different from what they are really like, so color contrasts, after-images and the subtraction of color and optical illusions can be explained by summing up the causes of color illusion.

Color systems (e.g. Colouroid, HSL, RGB, CMY, CIE) and color collections (e.g. Panton, Munsell) can be reached by classifying the explanation for color relations into a system. Color systems suggest that certain color assemblies within the system harmonize. The main goal and sense of color combinations is to create harmony. In fact, this allows students to get to know monochrome, dichrome, trichrome and tetrachrome harmony types and the way they are created. Then they study the effects of the color relations created, the way they are applied, options of usage, as knowing how to apply color harmonies is indispensible for students in the course of planning.

6. Means supporting learning the teaching material

Apart from traditional means and materials used forprocessing color theory material and its creative application it is also supported with an interactive computerized color theory educational software of our own development. By applying them synchronically, a means system has been developed for simultaneous obtainment of information, while being complementary to each other and making the discovery of reality fuller.

6.1. Traditional means

Traditional means applied in Short Color Courses are paints (such as waterpaint, tempera, print paint), bright light lamps, colored paper, printed color cards, colorful banner, and a rotation disc used for blending paint colors, which is brought about by converting an old tumble-dryer.

Colored paper (which may be pre-produced colored sheets, or pieces of paper clippedout of magazines, journals, advertisements, posters, illustrations and various catalogues) or is preferred for preparing color comparing tasks or creating color collections in the lessons. Paper allows for using a wide-range of hue, lightness andsaturation scale to be used directly, if a wide range of paper is available, and the same color can be used several times without changing its color properties, or its surface propeties changing at all.

6.2. Interactive color theory teaching program

"Applying computer technique makes the learning process unique." (Karvalics)

The development of the Color theory educational software was launched at the Faculty of Technology of Debrecen University in 2011. As a result, it allowed for mastering color theory, a deeper understanding and classification of the material.

Elaborating the software is part of the methodological research whose aim is to reveal efficient application of computer use in teaching mathematics, phisics, geometry and color theory. Computer applications have to be involved into education so that it would help us to recognize the link between theory and practice while maintaining interest in the subject in question by fostering the experimental spirit of students (see [11]).

In Short Color Courses mediated knowledge appears verbally and through picture coding while texts, pictures and interactive animation are used. The educational software is suitable for developing students' color sensitivity, their color-defining, color-distinguishing skills and for measuring the knowledge and skills mastered.

Sovány says in ([20]): *"Interactive multimedia systems are especially suitable for creating an effect mechanism perfectly fitting the information recording and registering mechanism of the human brain, while mediating knowledge."*

The efficiency of multimedia programs is owing to the fact that desired content can be reached very quickly and conveniently (see [12]). The advantage of the educational software developed by us compared to traditional means is as follows:

- it allows students to prepare on their own from the teaching material available;
- students can carry out basic experiments and tasks by themselves as well as obtain further information depending on their interests;
- the material presented can be used by several age groups of various standards;
- it contains a variety of tasks;
- it contains tasks of various complexity, that is its approach is;
- there is a chance for reproduction;
- it can test students (pre and post tests);
- both the instructor and the students use it in the teaching process.

Furthermore the software is simple, easy to use and platform-free (can be used on any operational-system).

7. Introducing tasks of the lessons

In this section, the main tasks are introduced, which were carried out with a multimedia teaching program in the lessons. Each task is analysed to reveal how the software has contributed to solving the problem, how the deficiencies of traditional technique and tools could be improved and how the difficulties cropping up in their use could be handled.

7.1. Color-blending tasks in the HSB system

As the three main properties of colors are their hue, saturation and brightness, it is recommended to analyse, compare and define color-patterns based on these properties. This is vital, as these experience and impressions define our choice of colors, our relationship to colors, in everyday life, during our planning, creative and implementing work.

The students get a sample of color, which they have to blend by using paints. Obviously, this is a rather difficult task as it is not easy to tell which of the three properties diverts from the given one, and to what extent the size and direction differ. In fact, this is where the ”Color-blending in HSB system” of our software can help.

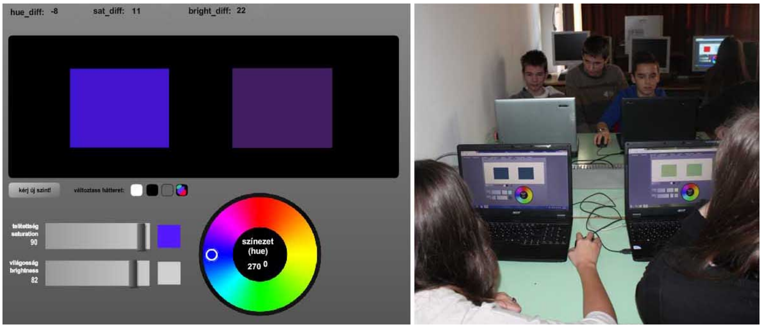

Figure 1: The HSB surface of educational software and its application

The color generated by the computer can be seen in the rectangle on the left of the panel of the module, and the students have to match the color-stock of the rectangle on the right with the color on the left. To achieve that, one can choose the right color from the color-circle below the colors (0–360°), fine-tuning its saturation and brightness using the sliders (0–100%). The black background currently running ban behind the rectangles can be modified to white, grey, mutlicolor or colored background. The values of difference between the sample defined in the program and the values of the blended paint (hue, saturation and brightness) can be seen above. The + and – signs indicate the direction of digression. The values of the digression in the initial stage of the blending practice offer many a + help, but this function can be switched off. While blending the colors, we are continuously comparing the two color samples by their three properties (see Figure 1).

7.2. Additive and subtractive color-blending tasks

“It is revealed by our experiences that newer and newer colors can be blended from any two or more colors. It is also a fact that any color can be created by blending the right number of base-paints. Any color can be created from the base colors in

two different ways, by additive or subtractive color-blending" (see [14]).This is the two-color-blending theory of crometics, which is applied in our daily lives.

In the blending of paint-colors (subtractive color blending), our students have had earlier practice. As a matter of fact this task can be made more spectacular by means of using a color-blending machine converted from a tumble-drier. By using only the three base-colors (Cyan, Magenta, Yellow) we can experience and study the formation of the blended colors (see Figure 2). Three kinds of print paint are the most suitable for his task. Students have no experience in blending light colors

Figure 2: Subtractive color blending in practice

(additive color blending). Three lamps are used for the experiment and the three base paints are Red, Green and Blue. Two-two colors covering each other create a lighter one, so the three colors blended produce white (see Figure 3). We try

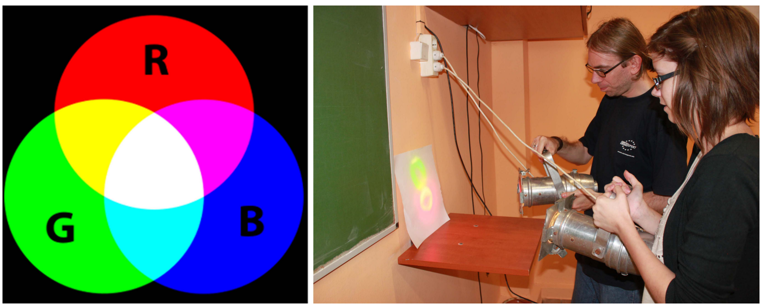

Figure 3: Additive color-blending in practice

to find out what the regularities of color blending are through experiments. On the other hand, if the color qualityis not the right one with the previous tasks, paint blending will not be suitable, i.e. the problem of material quality might prove misleading. When using colored lights the intensity of colors cannot be modified, our tool limits options of variability, so we cannot blend colors of all hues. These problems are eliminated by the task “Color blending in different color systems” of our educational software (see Figure 4).

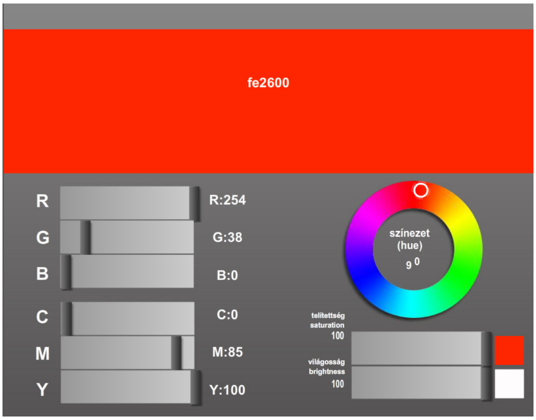

Figure 4: Colour blending in different color systems (RGB, CMY, HSB)

Additive and subtractive color blending is simulated in the educational software. The user can adjust the ”light intensity” of certain light displayswith the slider, and can observe the blending colors formed as well as their color codes. Now, we have a chance to introduce the regularities of creating colors (see Figure 5).

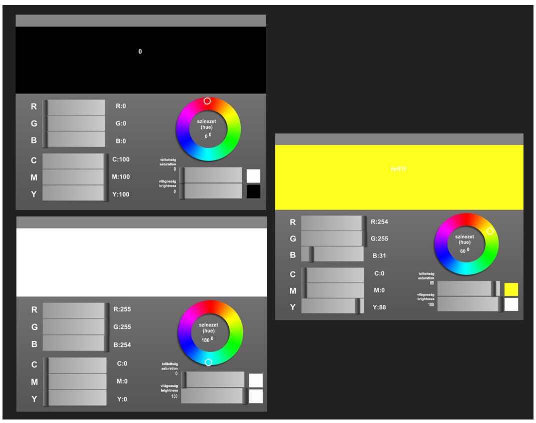

Figure 5: Testing the regularities of color blending

7.3. Color comparing tasks

The task is to compare identical hue – different brightness, or identical hue – different saturation colorpatterns, and also different hue – different brightness, different hue — identical brightness color patterns. The students' color distinguishing skills and their color sensitivity can be developed by doing color comparison tasks.

With traditional means we have as many experiments available as the number of color cards we have made by painting or printing (see Figure 6), so the number of experiments is limited. There are several experiments available for colour

Figure 6: Color comparison tasks with colored cards

stimulation coordination in our educational software, which differ either in terms of brightness or saturation values.

Figure 7: Color comparison tasks in our educational software

The task is to decide which one is a brighter with an identical color and identical saturation value, and which one is more saturated with identical color and identical brightness (see Figure 7). The educational software generates both color patterns at random, so that the difference in value between the colors to be compared is more and more narrowed down to a random number.

7.4. Creating saturation and light scales and their combination

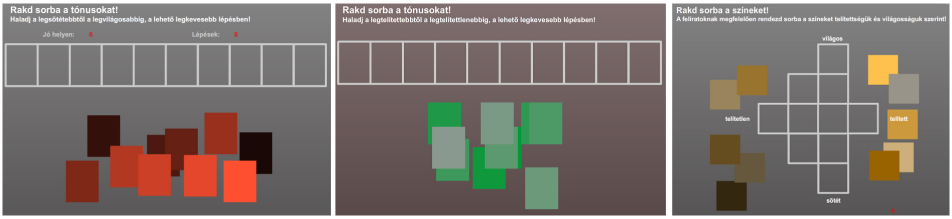

Figure 8: Saturation and light scales in the educational software

The task is to sequence the color patterns by brightness or saturation in rising or falling order, and then place the color patterns in a dark-bright-saturated-unsaturated system in the given formation. The latter task is rather difficult as the color patterns need to be compared from various aspects (see Figure 8). This task actually develops students combining skills (see [15]).

7.5. Color harmonies

Applying color harmony is of primary importance in ornamental art and in planning and implementing work (in the case of an object, a document or even a colorful building). In terms of the number of colors in the color assembly, there are monochrome, dichrome, trichrome and tetrachrome color harmonies. The ed-

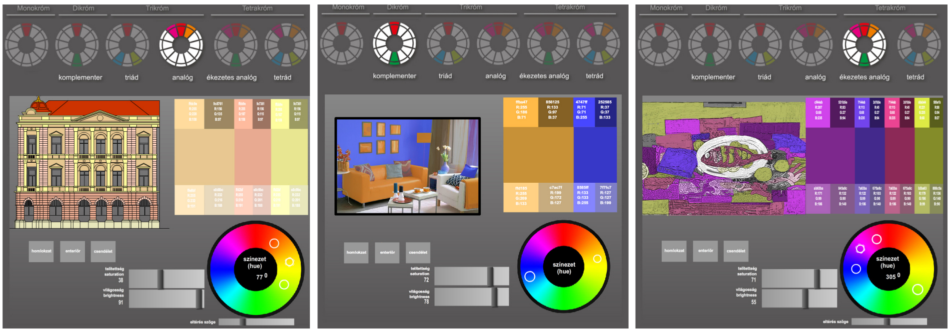

Figure 9: Color harmony types

ucational software allows one to get to know different types of harmonies and to test their applicability in different themes (see Figure 9). A possible means of raising enthusiasm about the subject and theme is experiments. By selecting the color from the set of colors, the software generates five color patterns of different saturation and brightness. The saturation and brightness values can be found by sliders. Our software is especially unique because it can make the color assembly we have created appear in different themes immediately. Thereby the color relations can appear on facades, inside buildings, in still life and grafics right away and can be studied (see Figure 10). György Pólya said that *"We should not only pass on*

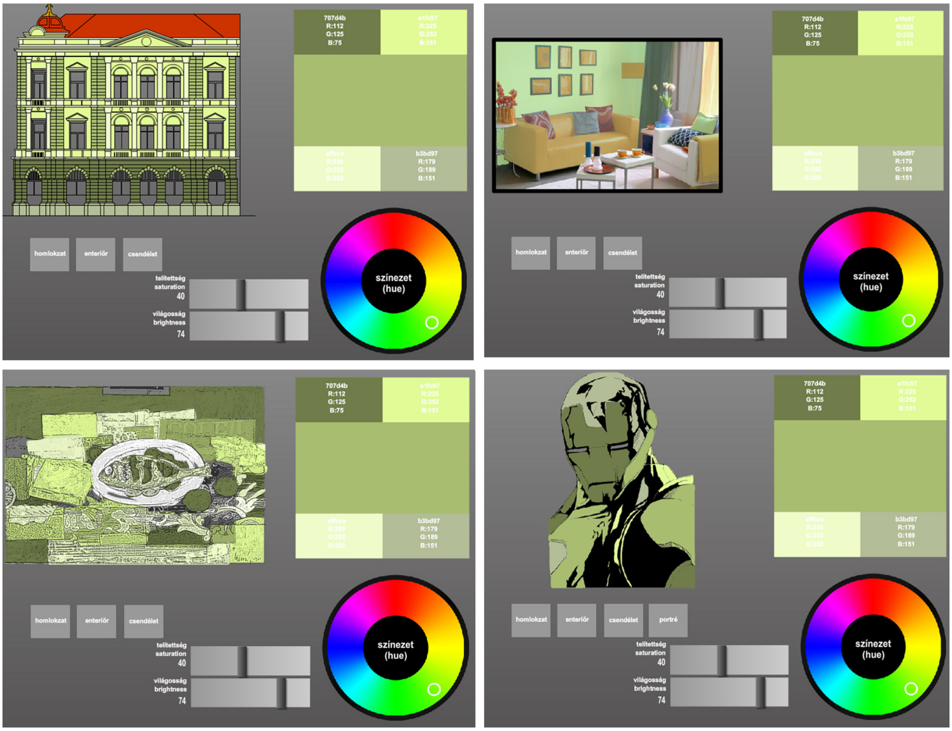

Figure 10: Monochrome harmony in different themes

knowledge to our students but we should also develop their capacity to think". Following his line of thoughts ([18]), we assume that it is not enough to know harmony types and we cannot fully be satisfied with harmony color assemblies either. The program actually offers an opportunity to examine what saturity and brightness of the chosen colors is reasonable to use in the chosen theme (see Figure 11). In fact, this allows our students to gain a lot of experience from observations and testing, which can be applied later in the planning process. An idea of the "Ten commandments for teachers ", written down by Mr Pólya in the 1950s should be mentioned here: *"Start looking for what can prove useful to solve problems to come in the current problems, and try to unfold the general solution behind the specific situations."*

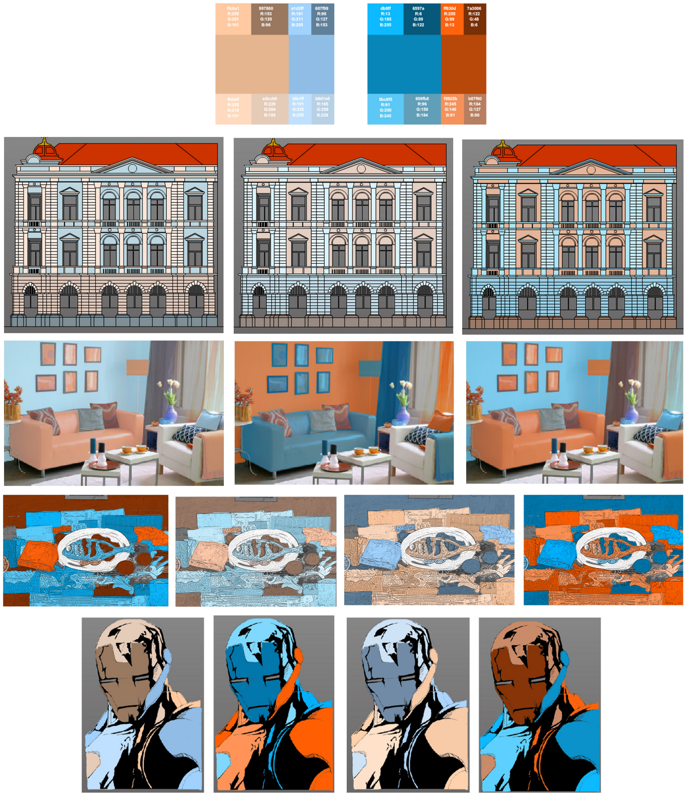

Figure 11: Dichrome harmony in different themes

8. Results and conclusions

It is important from the aspect of effects influencing the success of studying to encourage students to be actively involved in the classroom, since it is learning from your own experience in the classes that is the most lasting. Based on the experience gained from the experiments attendants of the Short Color Courses brushed up their knowledge of color theory in the different subjects, made up for their deficiencies and classified their knowledge. By developing their abilities (color sensitivity), they became capable of creating sensual color complexes, color harmonies from fine hues. It can be pointed out that the attendees of the Short Color Courses could apply colors better at the end of the course owing to the work carried out. At the end of the Short Color Courses we discussed with students what they had learnt from the classes and how useful they considered their experiences. Their positive feedback suggested that they had gained very rich experiences and found it very interesting that the very same theme had been approached from a completely different aspect. In fact, some of them actually realized that they had learnt about the same issue before. Also, they found the tasks pretty varied, the students liked the tools applied found the educational software user-friendly and varied as well as a great experience. They also added they would like to use the software later on in teaching and would have liked to spend more time learning about it.

We also asked teachers offering special classes to test how efficiently the students had learnt to apply their knowledge in practice. The feedback pointed out that secondary-school students managed to incorporate the knowledge mastered in Short Color Courses, and they integrate their knowledge into their new tasks of design and implementation in the lessons creatively. When it comes to solving specific tasks the color assemblies of color harmonies are employed in the process of planning. Further, they enjoy using the software even after the lessons to learn new things, revise their knowledge, practise and experiment.

Physics, biology, drawing and informatics teachers of several schools have let us know that we should help their work by offering lessons. That is why we would like to contribute to students' mastering color theory in the different years.

The question of which subject students like or not is an important signal evaluating the standards of pedagogical-methodological culture that can be experienced in the teaching of the subject (see [4]).

While Short Color Courses for secondary-school students were in progress, the method was also tested at the University of Debrecen, Faculty of Engineering. Statistical methods were applied to verify whether our novel approach resulted in improvement of students' color aptitude and their ability to match and distinguish colors. A paper reporting the results of the experiment is currently under review at Teaching Mathematics and Computer Science (see [17]).

Our method proved successful after several years of testing. During the methodological test the functions of the software were also tested. The training material is being further developed and new modules are being integrated.

While agreeing with views emphasizing the importance of the teaching-aid function of computers, we suggest that the method should be applied widely. To facilitate achieving that we wish to make the software available when all its functions are activated and it has proved useful both technically and methodologically.

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