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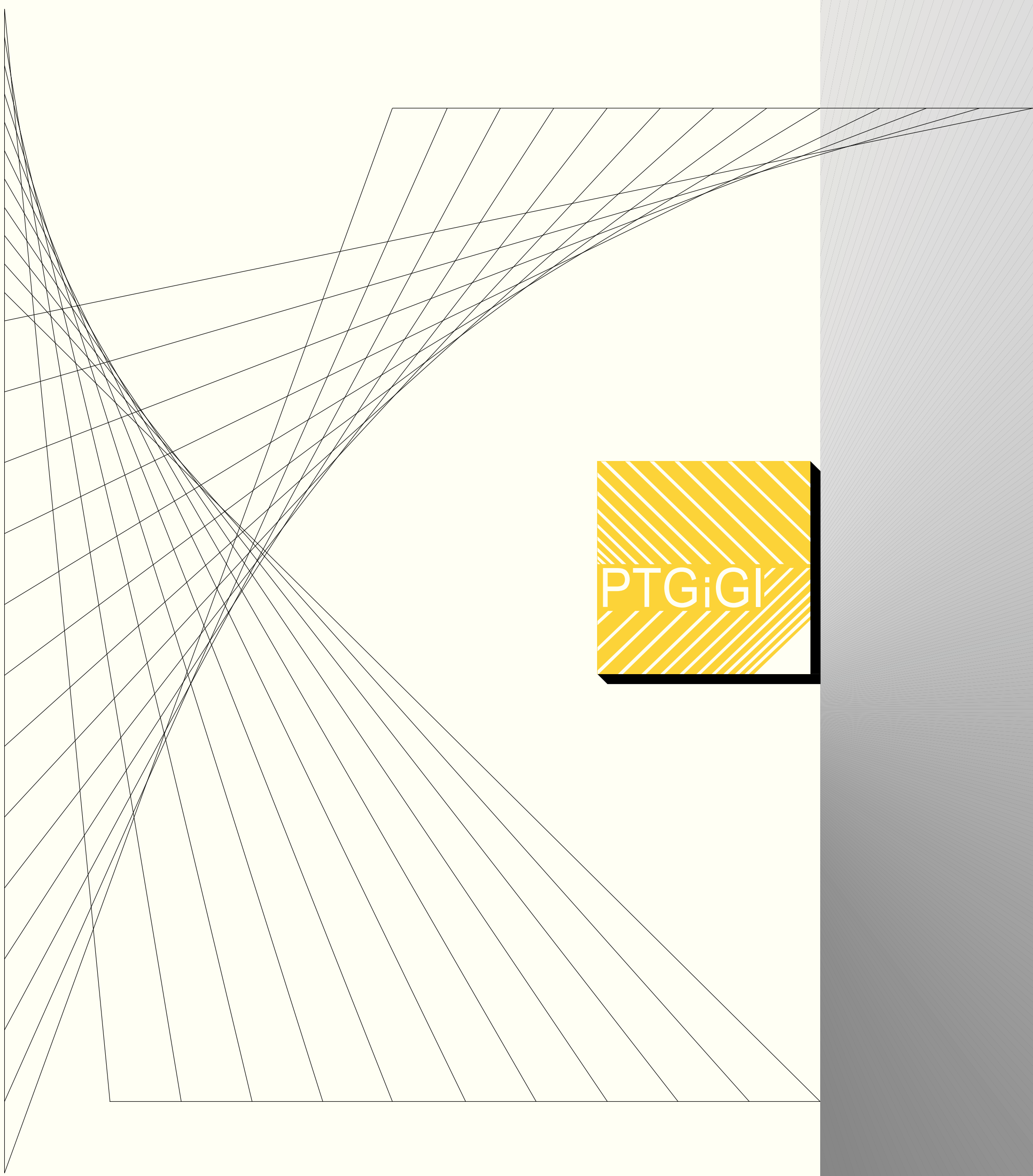

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INSTRUCTIONAL EFFECTIVENESS OF DIRECTIONAL ARROWS USED IN THE AUTHOR'S METHOD OF AUTOCAD TEACHING

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Abstract: The participants of trainings who learn the computer aided design using AutoCAD have often problems with spatial orientation, intuitive determination of coordinate axes' directions, and drafting with Cartesian coordinate system. These deficiencies are revealed while drawing on two-dimensional XY planes (2D) and in three-dimensional XYZ space (3D). Pedagogical experiment showed that learners who used monitors equipped with directional arrows indicating the directions of X & Y axes, demonstrated 18% better results on transfer tests of skills of rapid drawing with AutoCAD than those ones who used monitors without these arrows. Gender, age and field of education were not factors differentiating tests' results. Participants using the arrows considered them to be moderately effective (average rating M_o=2.02 on five-point scale of 0 to 4), wherein the older people assessed their educational suitability far higher ($M_{o>50}$=2.59 & M_{o41-50}=2.23 versus M_{o0-30}=1.82). The results of the study confirm the usefulness of simple teaching aids for technical education.

Keywords: spatial orientation, computer design skills, coordinate system, teaching aids

Introduction

Computer-aided design software (CAD) is a tool for drafting two- and three-dimensional plans and objects in coordinate systems. Effectiveness of trainings of CAD operators depends on their ability to correctly perceive the space and to intuitively recognize directions [1]. Each engineer should have these skills [2]. Students with higher spatial abilities found CAD software as easier [3] and showed greater functional and aesthetic creativity while performing 3D designs than students with limited spatial abilities [4]. David F. Lohman & Patrick C. Kyllonen suggest that human spatial abilities are shaped by three indicators: spatial relations, spatial orientation, and spatial visualization [5], while Lindsay A. Tartre limits the scope of the indicators to spatial orientation and spatial visualization [6]. Learners may have disordered spatial orientation [7] which causes difficulties in the practical use of 3D images [8], defined as "inability to determine one's true body position, motion, and altitude (or, in water, depth) relative to the earth or one's surroundings" [9].

Spatial disorientation is a symptom of developmental dyslexia leading to difficulties in understanding drawings, diagrams, spatial objects, in location elements and in determining their positions relative to each other, as well as in orientation on the maps [10]. Spatial disorders together with other individual features influence on degree of learners' perception of three-dimensional images [11]. They also decrease human ability of planning and imaging the spatial systems which define the planes on AutoCAD interface, therefore "engineering educators must analyze the possible attributes that make the 3D environment difficult for students to use, as well as the various teaching aids that can assist the student in understanding and becoming efficient in the operational 3D modeling environment" [7].

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James L. Mohler [7] suggests to reduce software learning curve by the use of mnemonic and multimedia devices, organizers, and visual aids, thanks to which learners "can more easily focus on the process instead of the tool or environment", and he encourages educators to design such teaching aids. The effectiveness of instructional tools was confirmed by higher results obtained on test of spatial skills by students learning CAD with PMR (Physical Model Rotator, used to synchronous rotation of real object and the same object visible in the scene) or with AVS (Alternative View Screen, equipped with two views of different representations of the same object, synchronously rotating, which allows the perception of differences between both representations) than results obtained by students learning CAD without these devices [12]. The natural ability of each man to self-explaining and to learn by self-explaining helps to develop spatial skills [13].

My experience of AutoCAD instructor gained during stationary courses for adults shows that learners often don't understand essence of operations performed in Cartesian coordinate system, they have difficulties with coordination of directions: left-right, up-down, and with spatial vision. To help them to initiate processes of self-explaining operations in space, and to overcome the limits of spatial disorientation, I designed directional arrows attached to monitors which showed the directions of X & Y coordinate axes. I used them during classes. Over the 6-years observation I noticed that people using the monitors with pinned arrows achieved proficiency in intuitive spatial drafting faster and they performed projects more correctly than users of monitors without arrows. The purpose of study described in this paper was empirical examination of instructional effectiveness of the directional arrows which were used during commercial, stationary basic AutoCAD courses for adults, hereinafter called trainings.

Three research questions (problems) were formulated:

1. What is the relationship between the use of directional arrows and the results of transfer tests of skills acquired by learners?

The studies were conducted under the conditions of commercial training, therefore it was impossible to select participants with spatial disorientation and with disorders of direction coordination which would be confirmed by specialist. For this reason the relationships between test results and the use of directional arrows were examined for all participants of trainings (not for subgroup of individuals with identified low spatial abilities).

2. What significance for the results of transfer tests of skills have a gender, age and field of education of learners who use directional arrows?

3. How participants of trainings evaluate effectiveness of directional arrows?

Research methods

Techniques, procedures and tools

In order to gather empirical material allowing for discussion of research problems I used the techniques of pedagogical experiment and survey questionnaire. Pedagogical experiment served to find answers to research questions of No. 1 to No. 3. The aim of the survey questionnaire was to provide data needed to investigate the problem covered by research question No. 3.

Participant of pedagogical experiment of randomly selected experimental Group E learnt with the use of monitors with instructional arrows pointing XY axis directions, while the control Group C benefited from the monitors without arrows and it was selected in such way that its structure of gender, age and field of education was as close as possible to the structure of group E. After the training E & C participants passed the transfer test of skills of fast AutoCAD drawing. Each learner drafted five specific projects. She/he could get from 0 to 10 pts for every task, i.e. from 0 to 50 pts for all test. The test lasted 1 hour.

The survey questionnaire contained demographic questions, in which particular persons specified their gender (female/male), range of age in years (<31, 31-40, 41-50, >50), and field of education (artistic, economic, humanities, technical, other), as well as one question “To what extent directional arrows placed on your monitor helped you to draw in AutoCAD? Rate their usefulness in five pts scale” in which respondents crossed one of five answers: 0-ineffective, 1–little effective, 2-average effective, 3-largely effective, 4-fully effective. The Group C completed the demographic part only while the learners from Group E completed all questionnaire.

Research groups

Pedagogical experiment included *N*=400 participants of trainings organized in Warsaw in 2007-2011 by two educational companies. From 8 to 12 persons took part in each of them. The classes were conducted using the same method and according to the same core curriculum. All learners had university degree at the undergraduate or graduate level. They had learnt AutoCAD never before.

Each of E & C Groups consisted of *n*=200 persons. In both groups the percentage of women was 54.0% (*n*=108) and the percentage of men was 46.0% (*n*=92).

Table 1 The age structure of the Groups E & C

Age subgroups [in years]	*n*; %	
	E	C
0-30	62; 31.0%	61; 30.5%
31-40	69; 34.5%	68; 34.0%
41-50	40; 20.0%	42; 21.0%
> 50	29; 14.5%	29; 14.5%

The numbers of participants in E & C age subgroups were similar (Table 1). In both groups the most learners were 31-40 years old (respectively 34.5%; *n*=69 and 34.0%; *n*=68) and fewer people didn’t exceed the age of 31 years (respectively 31.0%; *n*=62 and 30.5%; *n*=61). Older participants aged between 41 and 50 years were significantly less numerous (respectively 20.0%; *n*=40 and 21.0%; *n*=42) and the participants aged over 50 were the least numerous (both groups of 14.5%; *n*=29)

Table 2: Education structure of the Groups E & C

Field of education	*n* (%)	
	E	C
Artistic	43; 21.5%	44; 22.0%
Economic	39; 19.5%	40; 20.0%
Humanistic	40; 20.0%	38; 19.0%
Other	31; 15.5%	30; 15.0%
Technical	47; 23.5%	48; 24.0%

E & C Groups were characterized by similar structure of education (Table 2). Most persons gained technical qualification (respectively 23.5%; *n*=47 and 24.0%; *n*=48) and artistic qualification (respectively 21.5%; *n*=43 and 22.0%; *n*=44). Fewer people declared humanistic education (respectively 20.0%; *n*=40 and 19.0%; *n*=38). and economic education (respectively 19.5%; n=39 and 20.0%; n=40). The people with other education created the smallest subgroups (respectively 15.5%; n=31 and 15.0%; n=30).

All participants of pedagogical experiment from the Group E filled out a survey questionnaire.

The tools

Survey questionnaire; Instruction for test of skills; Computer stations; AutoCAD software; Directional arrows; SPSS package; Ms Excel spreadsheet.

Description of directional arrows (Fig. 1)

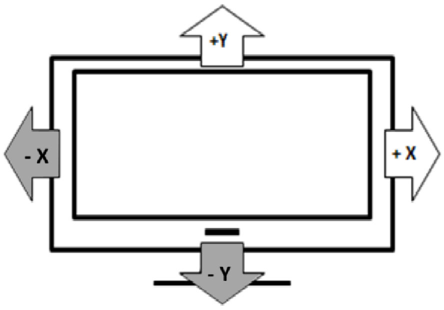

Figure 1: Directional arrows attached to the monitor

Directional arrows were made in the form of cardboard arrows indicating the directions and senses of the axes of XY coordinate system. Blue arrows (in the Fig. 1 shown in white) presented positive senses of X and Y axes, and were described as + X and + Y, The green ones (in the Fig. 2 shown in grey) indicated negative senses, and were described as -X and -Y.

Results and discussion

Study results were discussed in the sequence of presented research questions.

The use of teaching aids in the form of directional arrows versus results of test of skills learnt by participants of E & C Groups.

One-factor analysis of variance (ANOVA) showed statistically significant differences between scores of test obtained by participants from E & C Groups (p<0.001; F=400.399. df=1).

Table 3: Comparison of descriptive statistics for average test scores obtained by E and C Groups [in pts]

Group	Mean M	Standard deviation SD	Standard Error	Variance SD^2	95 % confidence interval for mean		Minimum Min	Maksimum Max
					Lower limit	Upper limit		
E	39.68	4.010	0.284	16.080	39.12	40.23	15	50
C	30.69	4.924	0.348	24.245	30.00	31.38	18	50

E Group achieved the mean test score M_E=39.68 pts higher by 8.99 pts than the mean test score of the Group C, M_C=30.69 pts (Table 3). Statistically significant differences between tests results gained by participants of E & C Groups were also confirmed by non-overlapping ranges of their 95% confidence intervals for means. In the case of E & C Groups the highest and lowest tests results were at a similar levels and amounted respectively Min_E=15 pts, Min_C=18 pts, and Max_E=Max_C=50 pts.

Twenty-five percent of the lowest test scores in E Group were from Min_E=15 pts to $Q1_E$=37 pts. In the case of C Group this range was smaller, from Min_C=18 pts to Q_{1C}=28 pts. Interquartile ranges of results gained by 50% of respondents from E Group determined by the value of first quartile $Q1_E$=37 pts and of third quartile $Q3_E$=42 pts was 5 pts, while the interquartile ranges of results obtained by 50% of C learners determined by the value of first quartile $Q1_C$=28 pts and of third quartile $Q3_C$=32.75 pts was 4.75 pts. Twenty-five percent of the highest scores of test in E Group belonged to the range between $Q3_E$=42 pts and Max_E=50 pts, and 25% of the highest results of test noted in C Group corresponded to wider range from $Q3_C$=32.75 pts to Max_C=50 pts.

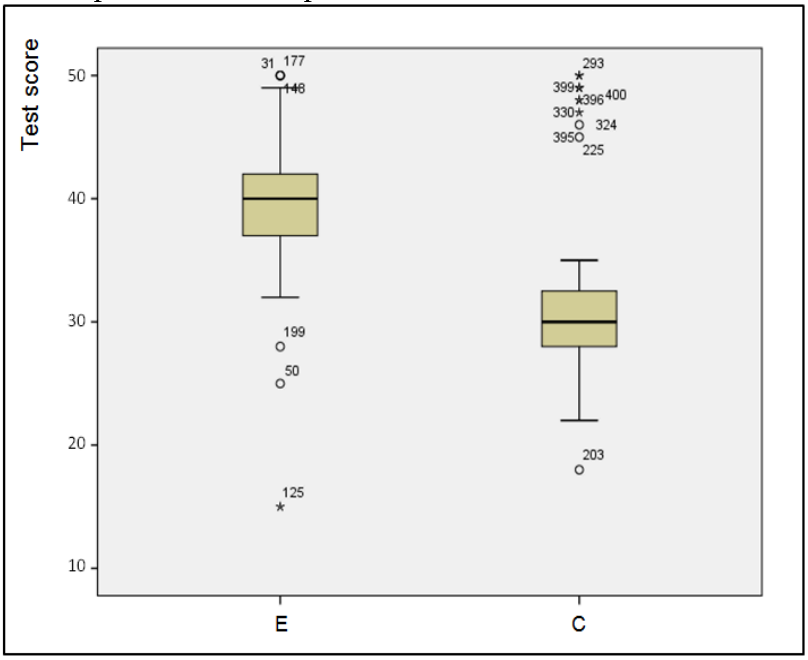

Figure 2: Boxplot showing variable Test result for the Groups E and C

In Fig. 2 the upper whisker of the box illustrating the scores of the Group E is slightly longer than the bottom one. This indicates the excess of higher scores, and reflects positive skewness of results distribution and the existence of atypical cases within the high values of variable. Above the upper whisker the outliers (marked on the graph by code numbers: *ID*=31, *ID*=177 and *ID*=148) correspond to the test results at the level of 50 pts. Deviants appear also below the bottom whisker of box E and they are represented by one extreme case of ID_{125}=15 and two outliers: ID_{50}=25, ID_{199}=28. Median of E Group amounting Me_E=40.00 is shifted toward $Q3_E$. This shows the left-side asymmetry in two middle quarters of results distribution.

Contrary to the box E, in the case of the box illustrating the results of C Group, bottom whisker is longer than the upper one, what indicates the excess of lower results and the negative skewness of their distribution, although atypical cases dominate within the high values of the variables and include five extreme cases (ID_{293}=50, ID_{399}=50, ID_{400}=48. ID_{296}=49, ID_{330}=48 pts) and three outliers (ID_{324}=47. ID_{395}=46. and ID_{225}=25). Median of results in C Group Me_C=30.00 is shifted towards $Q1_E$ indicating right-sided asymmetry in the two middle quarters of results distribution. The presence of deviants above and below of the box E confirmed higher leptocurticity of test results distribution in the case of E Group than in the case of C Group for which deviant results dominate over the box C.

Relationships between gender of participants from the Groups E and the results of test of skills learnt by them

The objective of the study was to verify whether gender affected results of test of skills learnt by users of directional arrows.

One-factor analysis of variance ANOVA didn't show statistically significant differences (p=0.857; F=0.032) between results of skills test acquired by women and by men from the E Group. The mean scores of both subgroups, respectively Mw=39.72 and Mm=39.62, differed by value of 0.10 pt that was within the limits of statistical error. Moreover 95% confidence intervals for these means overlapped.

Relationships between age of participants from the Group E and the results of test of skills learnt by them

The study investigated the relationship between age of learners benefited from directional arrows and results of test of skills acquired by them.

Table 4: Average test results of participants from the age subgroups E and their confidence intervals

Age subgroups [in years]	*n*	Mean *M* [pts]	95% confidence interval for mean	
			Lower limit [pts]	Upper limit [pts]
0-30	62	40.13	39.25	41.00
31-40	69	39.38	38.28	40.48
41-50	40	39.70	38.56	40.84
> 50	29	39.38	37.71	41.05

One-factor analysis of variance ANOVA didn't show statistically significant differences between scores of transfer test of skills gained by participants from five age subgroups E (p=0.724; F= 0.441). The difference between the lowest average test result (M_{E31-40}=39.38 pts for the age subgroup of 31-40 years) and the highest one (M_{E0-30}=40.13 pts for the age subgroup of 0-30 years) was 0.75 pts only, while 95% confidence intervals for these means overlapped largely (table 4).

Relationships between fields of education of participants from the Group E and the results of test of skills acquired by them

Analysis carried out by one-factor ANOVA didn't confirm the statistically significant differences (p=0.977; F=0.115) between results of tests obtained by learners from six subgroups E representing various fields of education.

Table 5: Average test scores of participants from the group E and their confidence intervals depending on the field of education

Field of education	*n*	Mean *M* [pts]	95% confidence interval for mean	
			Lower limit [pts]	Upper limit [pts]
Artistic	43	40.00	38.96	41.04
Economic	39	39.44	38.51	40.36
Humanistic	40	39.73	38.64	40.81
Other	31	39.55	38.56	40.54
Technical	47	39.62	37.81	41.42

The difference between the lowest mean subgroup result (M_{EE}=39.44 pts for economists) and the highest one (M_{EA}=40.00 pts for artists) was only 0.56 pt, with overlapping 95% confidence intervals for the means of all subgroups (Table 5).

Assessment of didactic value of directional arrows made by the participants from the Group E

Analysis of the responses of the respondents from the Group E *(n*=200) to the survey question regarding the assessment of educational effectiveness of directional arrows used by them during training showed an average score at the level of Mo=2.02 pts (on a scale of 0-4 pts), with a standard deviation SD_O=1.121 and the variance SDo^2=1.256.

Ten and a half percent of respondents (n=21) assessed the arrows as ineffective (0 pts); 21% (n=42) considered them to be little effective (1 pt); 33.5% (n=67) confirmed their average effectiveness (2 pts); 26% (n=52) identified arrows as a largely effective (3 pts), and 9% (n=18) indicated the answer: fully effective (4 pts). The histogram of arrows effectiveness ratings made by the respondents is illustrated in Fig. 3.

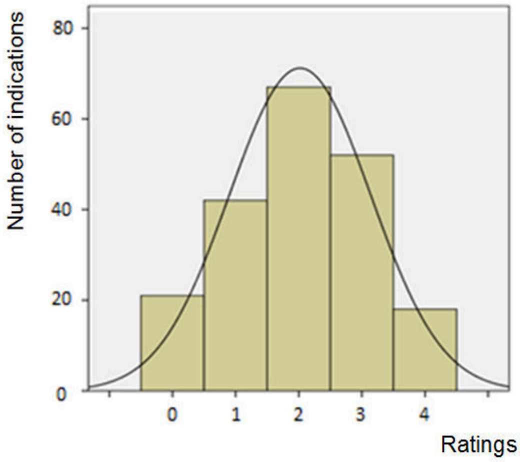

Figure 3: Prevalance of arrows effectiveness ratings made by respondents from the Group E

The study didn't confirmed significant correlation between ratings of instructional effectiveness of arrows granted by respondents from the Group E and the results of their tests achieved by them r=-0.066, p=0.356).

Moreover one-way ANOVA didn't show significant differences between arrows evaluations made by men and by women (p=0.816; F=0.054; df=1, with overlapping 95% confidence intervals for the means) and insignificant differences between arrows evaluations made by respondents with various education (p=0.255; F=1.344; df=4, with overlapping 95% confidence intervals for the means). One-factor ANOVA confirmed however significant differences between arrow ratings made by the learners from different age subgroups (p=0.005; F=4.354; df=3, with partially overlapping 95% confidence intervals for means). The participants from the oldest age subgroup (>50) evaluated the effectiveness of the arrows the highest $Mo_{>50}$=2.59 pts, respondents of the age subgroup 41-50 years admitted it Mo_{41-50}=2.23 pts, while respondents from two youngest age subgroups 0-30 years and 31-40 years assessed the effectiveness of the arrows significantly lower, respectively Mo_{0-30}=1.82 pts and Mo_{31-40}=1.84 pts.

Table 6: Multiple comparisons of ratings of arrows effectiveness made by particular age subgroups (by Sidak test)

Age (I)	Age (J)	Difference of means (I-J)	Standard error	Significance *p*	95% confidence interval for mean	
					Lower limit [pts]	Lower limit [pts]
0-30	31-40	-0.018	0.191	1.000	-0.53	0.49
	41-50	-0.402	0.222	0.357	-0.99	0.19
	>50	**-0.764***	**0.246**	**0.013**	**-1.42**	**-0.11**
31-40	0-30	0.018	0.191	1.000	-0.49	0.53
	41-50	-0.384	0.217	0.387	-0.96	0.19
	>50	**-0.746***	**0.242**	**0.014**	**-1.39**	**-0.10**
41-50	0-30	0.402	0.222	0.357	-0.19	0.99
	31-40	0.384	0.217	0.387	-0.19	0.96
	>50	-0.361	0.267	0.690	-1.07	0.35
>50	**0-30**	**0.764***	**0.246**	**0.013**	**0.11**	**1.42**
	31-40	**0.746***	**0.242**	**0.014**	**0.10**	**1.39**
	41-50	0.361	0.267	0.690	-0.35	1.07

*difference of means is significant at the level of $p \leq 0.05$; significant differences highlight in bold.

Sidak test demonstrated significant differences between the arrow effectiveness ratings made by the 0-30 age subgroup and by >50 age subgroup (difference of 0.764 pts at $p=0.013$ and non-overlapping 95% confidence intervals for means), and between analogical ratings made by the 31-40 age subgroup and by >50 age subgroup (difference of 0.746 pts at $p=0.014$ and non-overlapping 95% confidence intervals for the means) (Table 6).

Conclusions

Participants of pedagogical experiment who during AutoCAD trainings benefited from didactic, directional arrows mounted on their monitors achieved significantly higher scores on transfer test of skills than participants who didn't learn by means of these arrows. Average test score of the users of arrows (M_E=39.68 pts on scale of 0-50 pts) was about 18% higher than average test score of persons who didn't use them (M_C=30.69 pts). Moreover more learners who used monitors with arrows gained higher results on tests than individuals working with monitors without arrows, in case of which it was noted the excess of lower results. Thus the pedagogical experiment confirmed that the teaching aids in the form of directional arrows facilitated the acquisition of skills of quick drawing in AutoCAD and helped in obtaining higher results on the transfer test of skills.

Noted lack of confirmation of relationships between gender, age, and education field of users of directional arrows and results of test of skills acquired by them may indicate the usefulness of the arrows for the whole population of training participants.

Learners using directional arrows evaluated them as moderately effective (*Mo*=2.02 pts). It was a surprise to me because during the classes participants often expressed their position about uselessness of the arrows and showed unwillingness to place them on their monitors. Therefore I was convinced that they considered them to be ineffective.

Education of participants and their gender were not factors differentiating assessing of educational effectiveness of directional arrows but such relation has been noted for the age factor. Older people granted higher ratings, what could be resulted of their greater life experience or of the fact that many years earlier they had had more contact with the simple teaching aids during their schooling. In contrast, lower ratings of effectiveness of the arrows granted by learners from the youngest subgroups (who achieved high results of their tests) might be caused by their little practice to benefit from simple teaching aids, by unawareness of having spatial disorders, or by their shame associated with admitting to inability to use the coordinate systems.

Belief of learners in relatively not very high effectiveness of educational arrows (M_o=2.02 pts) might be also result of the fact that the participants of AutoCAD trainings were usually professionals who daily drew or read graphic designs, and they believed erroneously in their good skills to use coordinate systems or considered the arrows as too primitive to help them.

Unawareness of the impact of directional arrows on human mental perception of space and directions may also result from the lack of confirmation of connection between evaluation of arrows effectiveness made by individuals and the results obtained by them on the test of skills (unconfirmed significance of correlation with respect to all Group E).

Recommendation

The experiment showed instructional effectiveness of directional arrows mounted on the monitors of all AutoCAD learners. It seems purposeful to continue research on defining their educational suitability for the people with spatial disorientation.

In the era of Internet and high technology the attention of educators and learners is focused largely on the sophisticated high-tech teaching tools. They can undeniably support the learning process but the manner of effective usage of them is still remaining in the phase of study. In addition, high-tech tools require of teachers and of their students to have advanced skills in using new technologies and to have easy access to them, what is often important barrier to their implementation in everyday instructional practice. Therefore we should not forget about the simple teaching aids. In fact, in many cases they can be equally or more effective than digital ones. Moreover some of them (e.g. directional arrows) can be performed by the teachers independently in a fast, easy, and cheap way. For these reasons you should encourage all participants of educational process to use this kind of the tools to teach and to learn.

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DYDAKTYCZNA SKUTECZNOŚĆ STRZAŁEK KIERUNKOWYCH STOSOWANYCH W AUTORSKIEJ METODZIE UCZENIA OBSŁUGI PROGRAMU AUTOCAD

Uczestnicy szkoleń uczący się projektowania wspomaganego komputerowo za pomocą programu AutoCAD mają problemy z orientacją w przestrzeni, intuicyjną identyfikacją kierunków i zwrotów osi współrzędnych, oraz z kreśleniem w oparciu o kartezjański układ współrzędnych. Niedomagania te ujawniają się podczas rysowania na płaszczyznach XOY I w przestrzeni XYZ. Eksperyment pedagogiczny wykazał, że uczący się korzystający z przypinanych do monitorów, dydaktycznych strzałek kierunkowych, wskazujących kierunki I zwroty osi układu współrzędnych XOY, uzyskują o 18% lepsze wyniki na testach umiejętności szybkiego kreślenia niż osoby, które strzałek nie stosują. Płeć, wiek i kierunek wykształcenia nie są czynnikami różnicującymi wyniki testów. Jednocześnie uczestnicy korzystający ze strzałek uważają je za średnio skuteczne (średnia ocen M_o=2,02 pkt w pięciopunktowej skali od 0 pkt do 4 pkt), przy czym wyżej ich przydatność dydaktyczną oceniają osoby starsze ($M_{o>50}$=2,59 i $M_{o41\text{-}50}$ =2,23 versus $M_{o\ 0\text{-}30}$ = 1,82). Wyniki badania potwierdzają przydatność prostych pomocy dydaktycznych dla edukacji technicznej.