Developing Experimental Learning in a Graphical Course Using Thurstone's Law of Comparative Judgment

E. Ramírez-Juidías, *Member, IAENG*, J. Tejero-Manzanares, J.L. Amaro-Mellado, *Member, IAENG*, and L. Ridao-Ceballos

***Abstract*—In this paper, one innovative educational experiment to help student obtain a better way to learn spatial vision in graphical course was carried out. After implementation of the improvements into a graphical engineering course, an evaluation study, through surveys, was conducted to investigate the effectiveness of this visual experiment. This empirical study provided one hundred and sixty four andalusian freshmen three types of visualization (2D static depictions, 3D computer depictions and an augmented reality environment that allows multiple participants to interact with 2D and 3D data) required to improve their skills related to spatial vision. According to results, most students showed positive attitudes toward this practice. In addition, students perceived positive impacts of this effort on their learning experience. The responses to surveys illustrated that students prefer 3D traditional learning, however they think augmented reality learning is no useful for better visual understanding of different objects.**

***Index Terms*—Learning, spatial ability, visual experiment**

I. Introduction

According to [1], along with progressive development of technology and science, computer-aided drafting (CAD) has already been a strong power to build 2D and 3D engineering graphics. The various effects within CAD can promote student' visualization skill and deepen their understanding toward object constructions, features and performances.

Others authors regard that engineering graphics are very important due to it offers more than just teaching the technical language, it also helps develop students' visual ability and three dimensional problem solving skills [2]-[3]. In this regard, [1] indicated that the importance of spatial visualization should be greatly emphasized due to the rapid growth of computer hardware and software technologies.

In another vein, augmented reality (AR), defined as an emerging technology with high relevance for teaching, learning and creative inquiry [4], has an important application in all engineering areas, because it allows us to interact with reality designed to verify proper use.

It is noteworthy that CAD and AR might not work for all kinds of learning. According to [5], learner characteristics or individual differences can account for different learning results in both CAD-based and AR-based learning environments. In recent years, there is more focus on the role of learner characteristics or individual differences on learning with visual representations [6]. The importance of considering individual differences in visual representations is also emphasized by [7]. The effects of learner characteristics on learning outcomes would enable instructor to adapt the nature of instruction to accommodate individual differences to improve learning outcomes [5].

Hitherto, most teaching-learning studies have attempted to apply different techniques aimed at improving student ability in all areas. However, none of them use the Thurstone theory. For this reason, the aim of this paper is to use paired comparisons to glimpse what the needs are of freshmen.

II. PRESENTATION

A. Literature Review

As [1] point out, the visual presentation of objects is expressed in a more explicit way, although pictorial drawings are occasionally used, multi-view drawings are still the main method employed in mechanical drafting for the complete description of an object. On the other hand, [8] indicate that the orthographic projection is necessary to be used for observing an object from different views, including front, side and top views, and systematically putting them on a piece of drawing paper to deliver the essential information to viewers.

As is known, in most of the time pictorial drawing can be easily understood by students without technical training [3]. According to [1], even though pictorial drawing has good

Manuscript submitted July 26, 2016.
Emilio Ramírez-Juidías is with the University of Seville, ETSIA, Seville, CO 41013 SPAIN (corresponding author, e-mail: erjuidias@us.es).
José Tejero-Manzanares is with the University of Castilla La Mancha, EIMIA, Almadén, Ciudad Real, CO 13400 SPAIN (e-mail: jose.tejero@uclm.es).
José L. Amaro-Mellado is with the University of Seville, ETSIA, Seville, CO 41013 SPAIN (e-mail: jamaro@us.es).
Luis Ridao-Ceballos is with the University of Seville, ETSIA, Seville, CO 41013 SPAIN (e-mail: luisridao@us.es).

comprehension to the observers, it fails to present the complex or detailed features of an object. To overcome the defects, students can create different pictorial drawings displayed in various directions for assistance.

A person gradually learns from concrete to abstract [3]. It is be noted in connection with the foregoing that [9] made an empirical study to compare the learning effectiveness between parts-to-whole (PTW) and whole-to-parts (WTP) in teaching engineering drawing. As a result, the WTP approach proved to accelerate learning of engineering drawing and spatial visualization skills. Therefore, and according to [10], to present learners with concrete images to begin with is the best means to help them understand the features of an object.

In another vein, empirical studies have examined the use AR-based technologies for teaching and learning in engineering [11-12]. According to [4], given that mobile AR is still an emergent technology and field of study, it is not surprising that the majority of these studies is of a qualitative nature and concentrates on the elicitation of affordances and constraints of AR for teaching and learning. Hitherto, only few quantitative studies exist that rigorously measure the effect of AR on learning performance.

Most of the studies reviewed examined the effect of AR on learning spatial abilities [4]. Regarding the area of engineering, in one of the first large-scale experiments [13] investigated the efficacy of AR for training spatial abilities using 215 high school students as participants, but a between groups comparison could not find clear evidence for the advantageousness of AR as a spatial ability learning tool. In contrast to such study, [14] also studied the effect of AR on learning spatial abilities using a textbook enhanced by a desktop AR system and found more promising results, as in a pretest-posttest classroom experiment with 49 university students the AR group showed a significant gain in spatial abilities. In the same vein, [15] used a mobile AR application as an educational tool in an architecture and building engineering course with 57 university students, and comparing students' final grades related to practical skills and spatial abilities with the grades of students of the same course in the previous year (control group without AR), they found a significant statistical difference indicating that the application of AR technology in the course helped to improve students' performance.

B. Thurstone's Law

According to [16], Louis Leon Thurstone, in 1927, pioneered psychometrics by using Gaussian distribution to analyze paired comparisons. Thurstone's model assumes that an option's quality is a Gaussian random variable. This models the fact that different people may have different opinions on the quality of an option. Each option's quality score is taken to be the mean quality of the corresponding Gaussian.

Consider the basic case of two options, where we let the Gaussian random variables A and B represent the quality of both option A and B as follows (1):

$$A \sim N(\mu_A, \sigma_A^2), B \sim N(\mu_B, \sigma_B^2) \tag{1}$$

Their probability density functions (PDFs) are (2):

$$p_A(a) = \frac{1}{\sigma_A} \cdot \varphi \cdot \frac{a-\mu_A}{\sigma_A}, \; p_B(b) = \frac{1}{\sigma_B} \cdot \varphi \cdot \frac{b-\mu_B}{\sigma_B} \tag{2}$$

where φ, φ (x) = $[1/(2\cdot\pi)^2]\cdot\exp(-0.5x^2)$, is the standard normal PDF (zero mean and unit variance).

Thurstone's model says that when a person judges whether option A is better than option B, they draw a realization from A's quality distribution and a realization from B's quality distribution, and then chose the option with the higher quality [17]. Equivalently, they choose option A over option B if their draw from the random quality difference A-B is greater than zero, P(A>B) = P(A-B>0).

Since A-B is the difference of two Gaussians, A-B is a Gaussian random variable, that is (3):

$$\begin{aligned} &A - B \sim N(\mu_{AB}, \sigma_{AB}) \\ &\mu_{\mathrm{AB}} = \mu_A - \mu_B \\ &\sigma_{AB}^2 = \sigma_A^2 + \sigma_B^2 - (2 \cdot \rho_{AB} \cdot \sigma_A \cdot \sigma_B) \end{aligned} \tag{3}$$

where μ_{AB} is the mean quality different of A-B, σ_{AB} is the standard deviation of the random quality difference A-B, and ρ_{AB} is the correlation between A and B.

Therefore the probability of choosing option A over option B is (4):

$$\begin{aligned} &P(A > B) = P(A - B > 0) \\ &= \int_0^\infty \frac{1}{\sqrt{2\pi\sigma_{AB}^2}} \cdot \exp\left[\frac{-(x-\mu_{AB})^2}{2\sigma_{AB}^2}\right] \cdot dx \\ &= \int_{-\mu_{AB}}^\infty \frac{1}{\sqrt{2\pi\sigma_{AB}^2}} \cdot \exp\left[\frac{-x^2}{2\sigma_{AB}^2}\right] \cdot dx \end{aligned} \tag{4}$$

By the symmetry of the Gaussian, (4) can be expressed (5):

$$\begin{aligned} &= \int_{-\infty}^{\mu_{AB}} \frac{1}{\sqrt{2\pi\sigma_{AB}^2}} \cdot \exp\left[\frac{-x^2}{2\sigma_{AB}^2}\right] \cdot dx \\ &= \int_{-\infty}^{\mu_{AB}} \frac{1}{\sigma_{AB}^2} \cdot \Phi \cdot \left[\frac{x}{\sigma_{AB}}\right] \cdot dx \\ &= \int_{-\infty}^{\frac{\mu_{AB}}{\sigma_{AB}}} \Phi(t) \cdot dt = \Phi\left(\frac{\mu_{AB}}{\sigma_{AB}}\right) \end{aligned} \tag{5}$$

where Φ(z) is the standard normal cumulative distribution function (CDF) (6):

$$\Phi(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} \exp\left[\frac{-t^2}{2}\right] \cdot dt = \int_{-\infty}^{z} \Phi(t) \cdot dt \qquad (6)$$

By inverting (5), we can obtain the mean quality difference μ_{AB} as (7):

$$\mu_{\mathrm{AB}} = \sigma_{AB} \cdot \Phi^{-1}(P(A > B)) \qquad (7)$$

where $\Phi^{-1}(x)$ is the inverse CDF of the standard normal [17]. The inverse CDF of the standard normal is also commonly known as the z-score or standard score since it gives the number of standard deviations that x is from the mean. Although traditionally, getting the z-score required large lookup tables, modern computers can calculate the inverse CDF function precisely [16].

According to [16], Thurstone proposed estimating P(A>B) by the empirical proportion of people preferring A over B, $C_{A,B}/(C_{A,B}+C_{B,A})$. Assuming we can estimate the standard deviation σ_{AB}, the estimator for the quality difference is (8):

$$\hat{\mu}_{\mathrm{AB}} = \sigma_{AB} \cdot \Phi^{-1}\left(\frac{C_{A,B}}{C_{A,B} + C_{B,A}}\right) \qquad (8)$$

Equation (8) is known as Thurstone's Law of Comparative Judgment.

C. *Participants*

One hundred and sixty four andalusian freshmen from three classes of one engineering degree (Industrial Engineering) at University of Seville (Spain) were committed to the empirical study.

This study was designed with objects displayed with different forms of isometric drawings, including 2D static and 3D animation, in addition to industrial pieces shown in AR. All participants were taught by the same instructors.

D. *Display of the Views Ability Test*

The topic of views ability test was "types of visualization to improve the skills of spatial vision". Four versions of display illustrated the features of objects that were used in this spatial ability test. Two versions of display were static in the forms of 2D graphics, one was exhibited by necessary and sufficient views of different industrial pieces, which were constructed by the forms of pictorial drawing (Fig. 1). The other was described as 3D computer depictions (Fig. 2) using Solid Edge ST7. The other two versions of display were presented in the form of 3D rendering graphic with Solid Edge ST7 (Fig. 3) and using the free app called Augment Reality (Fig. 4). All displays of animation were presented five times for every object. These animations were presented without verbal or written descriptions and participants could not arbitrarily control these animations [1].

According to [18], the application of 3D models might easily increase cognitive load to students with low spatial ability. Therefore, by means of slowing the animation speed, eliminating verbal or written descriptions, and increasing the frequency of the animation are beneficial to this study.

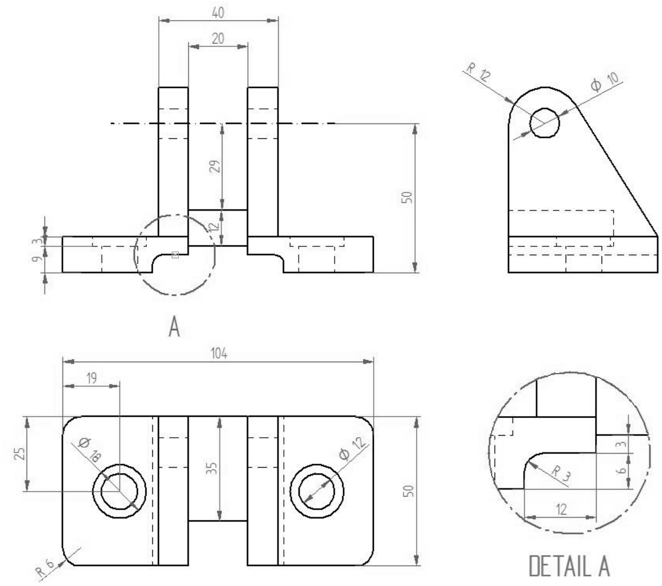

Fig. 1. Necessary and sufficient views of an industrial piece.

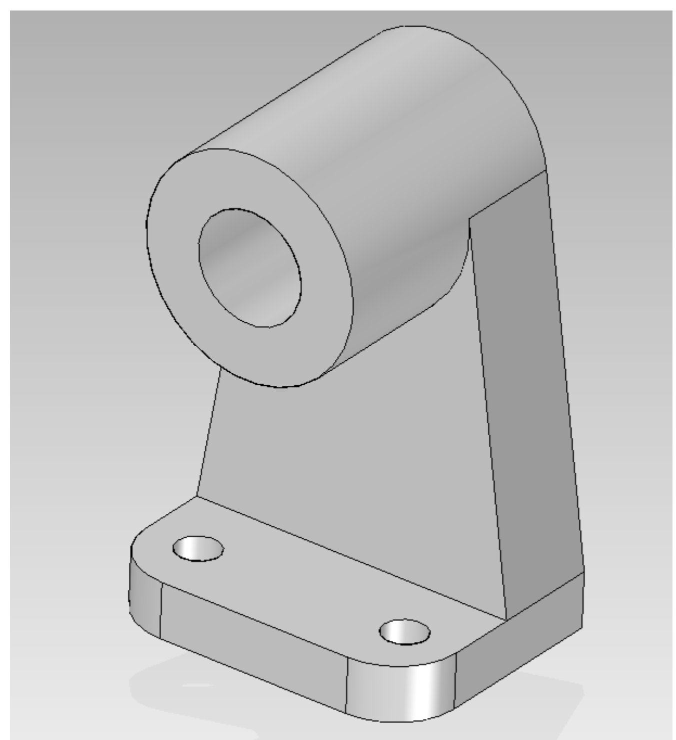
Fig. 2. 3D computer depiction with Solid Edge ST7.

The experiment was conducted in February 2015. In this study, all objects (2D, 3D and AR) were presented as paired comparisons.

E. *Analysis*

After completing the visualization of all paired comparisons, all freshmen filled a simple questionnaire with ten questions. The questionnaire documented their

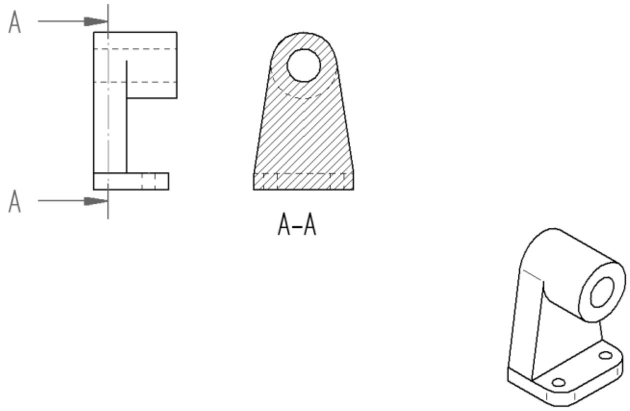

Fig. 3. 3D rendering graphic with Solid Edge ST7.

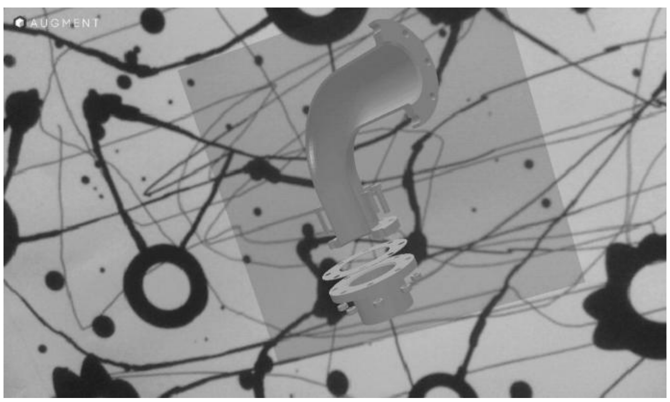

Fig. 4. Augment Reality free app.

comprehension of orthographic views toward different versions of display. All questions were asked to determine which version of display was the participant's favorite. Various data sources were collected to evaluate the students' comprehensive outcomes. In order to assure the efficiency of views ability test, eleven experts' opinions were required. All experts are professors from different Spanish universities. These experts were asked to inspect if the questionnaires were correlated to the related fields, as [1] specify.

The answers of each participant were computer-processed with adequate statistical software. Analysis of the data included comparison between different types of visualization (2D, 3D and AR), in addition to know the kind of learning that the freshmen prefer.

III. RESULTS AND DISCUSSION

Tables I and II give an overview of the test scores. In general, all results are in line with expectations. The difference between scores of the pretest and posttest could be because, at the beginning of the graphical course, freshmen had only little prior knowledge about the topics covered in this study.

The score scale of each compared pair (A vs B) were from -5 to 5 (-5,…, -1, 0, 1,…, 5), where 0 is equivalent to indifference between A and B. Maximum and minimum values presented in tables I and II correspond to those marked by participants.

As can be observed in tables I and II, there are significant differences between the scores of pretest and posttest. Freshmen generally positively value traditional learning, perhaps due to low use of both CAD and AR tools in high school.

TABLE I
DESCRIPTIVE STATISTIC OF PRETEST

	Min	Max	Mode	SD
Traditional Learning	5	-5	3	2.87
Computer Learning	5	-5	0	2.33
Augmented Reality L.	-5	5	0	2.98
Spatial Perception in TL	-1	-5	-3	1.21
Spatial P. in CL	1	5	5	1.29

TABLE II
DESCRIPTIVE STATISTIC OF POSTTEST

	Min	Max	Mode	SD
Traditional Learning	5	-5	3	2.72
Computer Learning	5	-5	3	2.14
Augmented Reality L.	-5	5	4	2.97
Spatial Perception in TL	-2	-5	-2, -5	1.52
Spatial P. in CL	1	5	3	1.14

Table III shows the assigned weights by participants in the pretest.

TABLE III
ASSIGNED WEIGHTS IN INITIAL TEST

	TL	CL	SPTL	SPCL	ARL
TL		-0.351	-2.610	-0.974	-1.221
CL	0.351		-2.377	-0.857	-0.065
SPTL	2.610	2.377		-1.688	-1.208
SPCL	0.974	0.857	1.688		-0.052
ARL	1.221	0.065	1.208	0.052	

As can be appreciated in table 3, there are important differences in the evaluation of different pairs. Students positively evaluated Traditional Learning (TL), as it was expected, because in previous years the graphical course was not taught via Computer Learning (CL) or Augmented Reality Learning (ARL). It is interesting to specify the weight assigned to the pair Spatial Perception in Traditional Learning (SPTL) vs Spatial Perception in Computer Learning (SPCL), -1.688, meaning that all participants recognize the importance of TL as basis for the development of spatial perception.

With regard to ARL, and given that in the initial test had not been used, it may think, regardless of the students knew the meaning of AR (85% ignored its definition), all participants have answered based on their preferences regarding the explanation specified in class on using the tool.

Figure 5 shows the scalar transformed values (STV) obtained from the scalar values for each item (SVI).

As was outlined, the students gave more importance to TL, because for them it is essential vehicle for the development of spatial perception (Fig. 5).

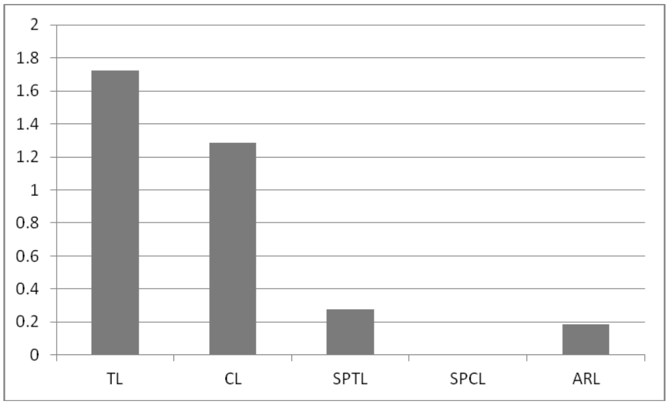

Fig. 5. STV obtained in pretest.

In order to see the evolution followed by all participants, an external evaluation was conducted in mid-February 2015. External evaluators were in classes observing the work of the students and after, they filled the same survey that those, with the difference that marked refer to how external evaluators perceived the development of freshmen via comparison pairs. The assigned weights by external evaluators and the STV are shown in table IV and Fig. 6 respectively.

TABLE IV
ASSIGNED WEIGHTS BY EXTERNAL EVALUATION

	TL	CL	SPTL	SPCL	ARL
TL		-3.909	-3.364	-4.182	-3.727
CL	3.909		-1.909	-2.545	-1.182
SPTL	3.364	1.909		-3.818	-2.273
SPCL	4.182	2.545	3.818		0.455
ARL	3.727	1.182	2.273	-0.455	

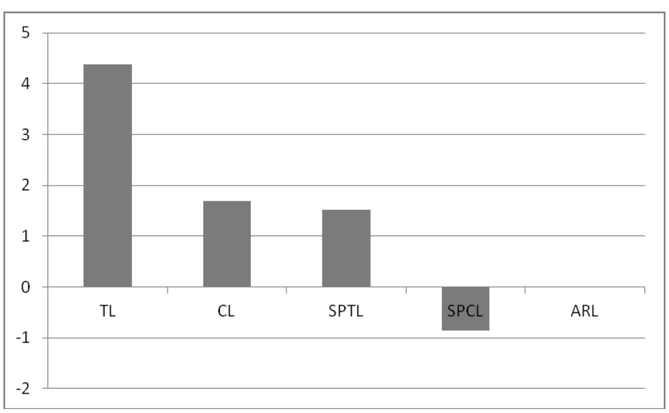

Fig. 6. STV obtained by external evaluation.

According to external evaluation, students better understand teaching-learning processes based on TL. However, although the use of new technologies applied to engineering degrees is booming since 2006 [4], students still have a great disconnect between the relationship of the object in 2D and its three-dimensional spatial projection.

External evaluators specified that ARL has no benefit in comparison with CL.

After making the improvements suggested by external evaluators, in late February 2015 the latest survey was performed, whose results are shown in table V and figure 7.

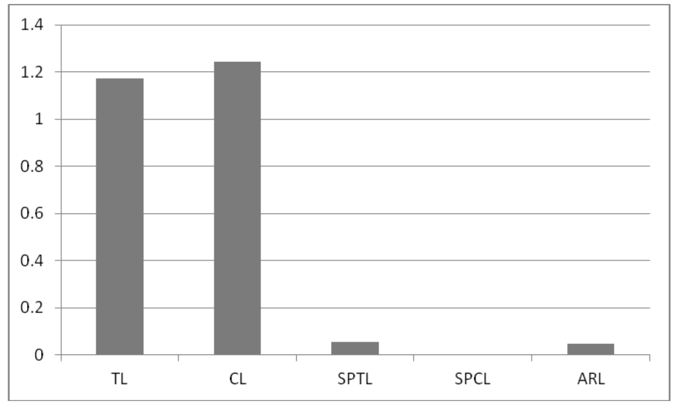

Fig. 7. STV obtained in posttest.

TABLE V
ASSIGNED WEIGHTS IN FINAL TEST

	TL	CL	SPTL	SPCL	ARL
TL		0.252	-2.423	-0.638	-0.540
CL	-0.252		-2.209	-0.883	-0.350
SPTL	2.423	2.209		-1.534	-0.859
SPCL	0.638	0.883	1.534		-0.534
ARL	0.540	0.350	0.859	0.534	

As can be appreciated in Fig. 7, students think for a proper understanding of the graphical course is required a theoretical basis based on TL and use of software that improves the overview, in 3D, of the represented object. For this reason, the STV of SPCL are null in both pretest (Fig. 5) and posttest (Fig. 7). In this final test all participants think ARL has not an important role to obtain a spatial understanding of the object. Likewise ARL neither favors the development of spatial ability of students.

According to the results of this innovative educational experiment, instructors think the use of 3D software technology should be implemented much more in order to make it easier for students to understand difficult objects, that is, objects with oblique or double-curved surfaces. Conversely, 2D static depictions will be a better and convenient choice when objects are constructed by simple shapes like normal, inclined and cylindrical surfaces [1].

IV. CONCLUSIONS

Recent advances in mobile technologies (tablets and iPods with cameras, internet access [19-20] and GPS) may be a great opportunity for development of new strategies to enable the appropriate development of spatial vision skills in graphical courses. However, it is necessary to consider the attitude of participants, as it is along with their particular characteristics of prior knowledge and effort which allows adequate results.

In this study, the evolution of spatial vision skills depended on the atmosphere created by the professor in class, with appropriate exercises, since in University of Seville each practice group has between 24 and 48 students, very far from the 5-10 participants per group with which [7] conducted their study, reason why collaborative strategies should have better results in those universities which, such as ours has still a high rate of students per professor.

As for assessing the freshmen' spatial perception skills, 3D animations can increase the effects of good performances. Thus, it'll probably become a more accurate way to evaluate the participants' orthographic views' ability.

Acknowledgment

E. Ramírez-Juidías thanks Universidad de Sevilla (II Teaching Plan) by the aid granted in the Plan for Innovation and Teaching Improvement 2013-14 (Ayudas de Innovación y Mejora Docente 2013-14), seed of this research.

References

[1] Chih-Fu Wu and Ming-Chin Chiang, "Effectiveness of applying 2D static depictions and 3D animations to orthographic views learning in graphical course," *Computer & Education*, vol. 63, pp. 28–42, Apr. 2013.

[2] J. L. Mohler, and C. L. Miller, "Improving spatial ability with mentored sketching", *Engineering Design Graphics Journal*, vol. 72, no. 1, pp. 19-27, Jan. 2008.

[3] E. Ramirez-Juidias, and L. Galan-Ortiz, "El Dibujo Técnico por Ordenador: Bases y Experiencias," in *XV Jornadas sobre el Acceso a la Universidad*, Universidad de Sevilla, Ed., Sevilla: Universidad de Sevilla, 2008, pp. 205-210.

[4] P. Sommerauer and O. Müller, "Augmented reality in informal learning environments: a field experiment in a mathematics exhibition", *Computer & Education*, vol. 79, pp. 59-68, Oct. 2014.

[5] E. Ai-Lim Lee and K. Wai Eong, "Learning with desktop virtual reality: low spatial ability learners are more positively affected", *Computer & Education*, Vol. 79, pp. 49-58, Oct. 2014.

[6] T. N. Höffler and D. Leutner, "The role of spatial ability in learning from instructional animations – evidence for an ability-as-compensator hypothesis", *Computers in Human Behavior*, vol. 27, no. 1, pp. 209-216, Jan. 2011.

[7] F. Meijer and E. L. Van Den Broek, "Representing 3D virtual objects: interaction between visuo-spatial ability and type of exploration", *Vision Research*, vol. 50, pp. 630-635, Mar. 2010.

[8] *Engineering Drawing and Graphic Technology*, 11^{th} ed., McGraw-Hill, New York, 1987, pp. 53-68.

[9] Z. A. Akasah and M. Alias, "Bridging the spatial visualization skills gap through engineering drawing using the whole-to-parts approach", *Australian Journal of Engineering Education*, vol. 16, no. 1, pp. 81-86, Sep. 2010.

[10] S. Olkun, "Making connections: improving spatial abilities with engineering drawing activities", *International Journal of Mathematics Teaching and Learning*, pp. 1-10, Apr. 2003.

[11] *The handbook of research for educational communications and technology*, J. Spector, M. Merril, J. Elen and M. Bishop eds., Springer, New York, 2014, pp. 735-745.

[12] H.-K. Wu, S. W.-Y Lee, H.-Y Chang, and J.-C. Liang, "Current status, opportunities and challenges of augmented reality in education", *Computer & Education*, vol. 62, pp. 41-49, Mar. 2013.

[13] A. Dünser, K. Steinbügl, H. Kaufmenn and J. Glück, (2006, Jul). Virtual and Augmented Reality as Spatial Ability Training Tools. Presented at Conference Proceedings of the ACM SIGCHI New Zealand chapter's international conference on computer-human interaction. [Online]. Available: http://dl.acm.org/citation.cfm?id=1152776

[14] J. Martin-Gutierrez, J. Luis Saorin, M. Contero, M. Alzañiz, D. C. Perez-Lopez and M. Ortega, "Design and validation of an augmented book for spatial abilities development in engineering students", *Computer & Graphics*, vol. 34, no. 1, pp. 77-91, Feb. 2010.

[15] D. Fonseca, N. Marti, E. Redondo, I. Navarro and A. Sanchez, "Relationship between student profile, tool use, participation, and academic performance with the use of augmented reality technology for visualized architecture models", *Computer in Human Behavior*, vol. 31, pp. 434-445, Feb. 2014.

[16] K. Tsukida, and M. R. Gupta. (2011, May). How to analyzed paired comparison data. University of Washington. [Online]. Available: https://www.ee.washington.edu/techsite/papers/documents/UWEETR-2011-0004.pdf

[17] L. L. Thurstone, "A law of comparative judgment", *Psycological Review*, vol. 34, pp. 273-286, Jul. 1927.

[18] T. Huk, "Who benefits from learning with 3D models?: the case of spatial ability", *Journal of Computer Assisted Learning*, vol. 22, no. 6, pp. 392-404, Apr. 2006.

[19] Y.-S. Chen, M.-T. Sung, S.-H. Fang and K.-L. Lin, "8051 NET-ISP: internet-based remote programmable embedded micro-controller system", *Engineering Letters*, vol. 23, no. 1, pp. 1-7, Feb. 2015.

[20] H. Miyajima, N. Shigei, H. Miyajima, Y. Miyanishi, S. Kitagami and N. Shiratori, "New privacy preserving back propagation learning for secure multiparty computation", *IAENG International Journal of Computer Science*, vol. 43, no. 3, pp. 270-276, Aug. 2016.

Emilio Ramírez-Juidías was born in Madrid City (Spain), in 1973. He received the B.S. degree in agricultural engineering from University of Seville, Seville, Spain, in 1998, M.S. degree in agronomical engineering from the University of Córdoba, Córdoba, in 2002, Ph.D. degree from University of Seville, Seville, in 2010 and M.S. degree in water engineering from University of Seville, Seville, in 2013.

Since 2001, he is Tenured Lecturer with the Graphic Engineering Department, University of Seville. He is the author of more than 40 books, more than 30 articles, and holds six patents. His research interests include computer-aided 3D modelling techniques for engineering, virtual animation and recreation, data acquisition and graphic description of industrial heritage, design of new product and remote sensing. He is member of Editorial Board of the journals Anduli, Wyno Academic Journal of Agricultural Sciences and Boletín de la Sociedad Andaluza de Entomología.

José Tejero-Manzanares was born in Almaden City (Spain), in 1968. He received the B.S. degree in industrial engineering from University of Castilla-La Mancha, Almaden, Spain, in 1986, M.S. degree in agronomical engineering from the University of Córdoba, Córdoba, in 2010 and Ph.D. degree from University of Cordoba, Cordoba, in 2011.

Since 1991, he is Tenured Professor with the Mechanical Applied & Project Engineering Department, University of Castilla-La Mancha. He is the author of more than 7 books, more than 40 articles, and holds one patent. His research interests include computer-aided 3D modelling techniques for engineering, virtual animation and recreation, data acquisition and graphic description of industrial heritage, design of new product and remote sensing. He is referee of Dyna Bibao journal.

José-Lázaro Amaro-Mellado was born in Jaén, Andalusia (Spain), in 1977. He received the B.S. degree in surveying engineering from University of Jaén, Jaén, Spain, in 1999, M.S. degree in engineer in geodesy and cartography from the University of Jaén, jaén, Spain, in 2002 and M.S. degree in graphic representation technics and design in engineer and geomatics from University of Córdoba, Córdoba, Spain, in 2007.

From 2005 to 2009, he worked (as a public servant) for the main national mapping agency (Instituto Geográfico Nacional-IGN) of Spanish government as a surveyor engineer and from 2009 he works as a geomatic engineer. From 2012, he is the head of IGN Andalusian Department and he teaches part-time in University of Seville from 2011. He is author of more than 15 journal and conference papers. His research interests lie in the field of computer-aided 3D modeling techniques for engineering, data acquisition and analysis, geomatics engineering, remote sensing and seismic hazard.

Luis Ridao-Ceballos was born in Seville City (Spain), in 1966. He received the B.S. degree in architecture from University of Seville, Seville, Spain, in 1996.

Since 2002, he is Assistant Professor with the Graphic Engineering Department, University of Seville. He has been awarded in more than five times for his architectural projects. His research interests include computer-aided 3D modelling techniques for engineering, virtual animation and recreation.