Proceedings - Actas

24th INTERNATIONAL CONGRESS ON PROJECT MANAGEMENT AND ENGINEERING

XXIV CONGRESO INTERNACIONAL DE DIRECCIÓN E INGENIERÍA DE PROYECTOS

ALCOY

07.07.2020
08.07.2020
09.07.2020

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Proceedings from the 24th International Congress on Project Management and Engineering (Alcoy, July 2020)

Comunicaciones presentadas al XXIV Congreso Internacional de Dirección e Ingeniería de Proyectos, celebrado del 7 al 9 de julio de 2020

AEIPRO

Asociación Española de Dirección e Ingeniería de Proyectos

ISBN 978-84-09-21128-9

Editado por AEIPRO

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El XXIV Congreso Internacional de Dirección e Ingeniería de Proyectos ha sido coorganizado por el Campus de Alcoy de la Universitat Politècnica de València (UPV).

09-018

COMPARATIVE STUDY OF TECHNICAL DRAWING METHODOLOGIES FOR SPATIAL VISION TRAINING

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New technologies and computer-aided design (CAD) applications have changed the teaching of technical drawing in recent years, leading its study towards new paradigms. These paradigms have allowed the emergence of different technical drawing methodologies for spatial vision training. During the first year of university studies, students of Engineering degrees study some basic Graphic Engineering subject. One of the main objectives of this subject is to improve the capacity of spatial vision. This work aims to study and compare different methodologies used to train the spatial vision in the subject of Graphic Expression of the degree of Agrifood Engineering, in which most of the students lack previous experience in technical drawing. A practical exercise has been proposed that consists in obtaining an axonometric view from its dihedral views through the use of three different methods: through the use of classic drawing instruments, through 2D computer delineation, and through 3D modeling. The results show that the classic drawing instruments allow obtaining quick and approximate solutions. 3D models improve spatial vision in students. The 2D delineation method allows for accurate solutions and a wider range of axonometric (not just isometric) views, but it also requires a major effort and time for students.

Keywords: graphic engineering; technical drawing; spatial vision; CAD

ESTUDIO COMPARATIVO DE METODOLOGÍAS DE DIBUJO TÉCNICO PARA ENTRENAR LA VISIÓN ESPACIAL

Las nuevas tecnologías y aplicaciones de diseño asistido por ordenador han cambiado la enseñanza del dibujo técnico durante los últimos años, dirigiendo su estudio hacia nuevos paradigmas. Estos paradigmas han permitido la aparición de diferentes metodologías de dibujo técnico a la hora de trabajar la visión espacial. Durante el primer año de estudios universitarios, los estudiantes de los grados de Ingeniería estudian alguna asignatura básica de Ingeniería Gráfica. Uno de los objetivos principales de esta asignatura es el de mejorar la capacidad de visión espacial. Este trabajo estudia y compara diferentes metodologías utilizadas para entrenar la visión espacial en la asignatura de Expresión Gráfica del grado de Ingeniería Agroalimentaria, donde la mayoría de los alumnos carece de experiencia previa en dibujo técnico. Se ha propuesto un ejercicio práctico que consiste en la obtención de una vista axonométrica a partir de sus vistas diédricas mediante tres métodos diferentes: mediante el uso de bocetos, delineación 2D por ordenador, y modelado 3D. Los resultados muestran que los bocetos permiten obtener soluciones rápidas y aproximadas. Los modelos 3D mejoran la visión espacial en los estudiantes. La delineación 2D permite soluciones precisas (no solo isométricas), pero requiere un gran esfuerzo y tiempo para los estudiantes.

Palabras clave: ingeniería gráfica; dibujo técnico; visión espacial, CAD

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1. Introduction

Graphic Engineering is a core subject that encompasses the students of different Engineering degrees. CAD technologies are constantly evolving, and the tendency in last years has been going towards new paradigms based on 3D modelling, as it has been considered as a requirement for future engineers properly prepared (Ye et al., 2004). For this reason, at Universitat Jaume I CAD 3D modelling has been introduced in the last years in this subject of technical drawing. The main objectives of this subject are to train the capacity of spatial vision in students and develop their knowledge of graphic representation techniques applying both, traditional methods of descriptive geometry and computer-aided design (CAD) applications.

Students of technical studies generally have to imagine objects in different positions and manipulate or generate graphic information, either on paper or on computer, using in this case both 2D or 3D CAD tools. Visual learning is key to develop appropriate skills in the fields of science and engineering (McGrath & Brown, 2005). These skills facilitate the collaborative learning and develop the students' creativity. Spatial thinking is essential for scientific thinking and is used to represent and manipulate information in learning and problem solving (eg. Smith, 1964; McGee, 1979; Clements & Battista, 1992).

The first problem faced by teachers is that students start their engineering studies with different levels of previous knowledge in technical drawing. This statement is the result of a study conducted in the course 2017/2018 with students of the same subject (Plumed, González-LLuch & Gómez-Fabra, 2018). In that work, a gamification experience conducted to obtain an initial evaluation of students is described. Results showed that half of students from Chemical and Agrifood Engineering had never received any training in technical drawing. This fact caused that in the last two years the Agrifood Engineering students were taught independently from the other Engineering degrees.

This paper is structured in the next sections: Section 2 argues the objectives of current work, section 3 describes the methodology used to carry out the survey in order to compare the methodologies followed to train students in spatial vision. Section 4 presents the analysis of the results and section 5 sums up the main conclusions obtained.

2. Objectives

Based on the planning of the degree, the subject of Graphic Expression is a core subject that is taught in the second semester of the first year of the degree in Agrifood Engineering and Rural Environment.

Students are intended to receive a coherent and integrated training which allows them to understand, analyse and solve problems or situations with a complete vision and applying the most appropriate tools in each case. Consequently, the main competence of the graphic engineering subject is to obtain spatial vision skills and knowledge of graphic representation techniques, both by traditional descriptive geometry methods and by means of computer-aided design applications. Learning outcomes focus on applying the ability of spatial vision to interpret and make engineering drawings, applying drawing techniques to obtain technical drawings, applying delineation techniques with 2D and 3D CAD applications, as well as understanding and applying the multiview system and axonometric representations.

This work aims to study and compare different methodologies used to train the spatial vision in the subject of Graphic Expression of the degree of Agrifood Engineering, in which most of the students lack previous experience in technical drawing. Specifically, it is intended to compare the training of spatial vision by three different methods: with classic drawing instruments, through 2D computer delineation, and through 3D modelling.

3. Methodology

The didactic proposal in the Graphic Expression subject structures the teaching-learning process in two training activities: theoretical teaching and practical teaching (lab sessions).

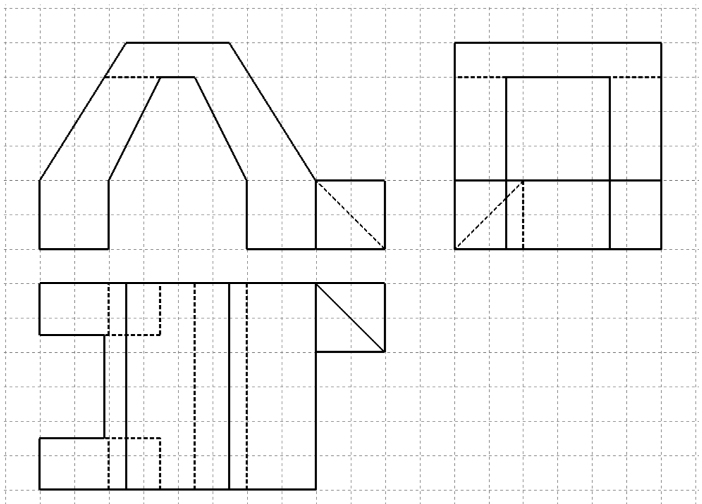
During the first weeks of the course, students are introduced to the fundamentals of the representation systems, which includes multiview projection and axonometric projection. To follow the classes, students can consult the first chapters of Plumed & Gómez-Fabra (2016). In the theory classes, students are also introduced to sketch drawings. Some exercises are performed with classical drawing tools (ruler, triangle & set-square) to practice the theoretical contents. Lab sessions take place in a computer lab and are aimed to learn specific engineering application software (in this case, AutoCAD in both, 2D and 3D environment). In these practices, the resolution of exercises and problems is proposed and carried out.

To determine whether students have achieved sufficient spatial ability to represent an object in different positions and with any representation methodology, a first midterm exam was performed. To complete the information, an online questionnaire was conducted where the students expressed their opinion on the different methodologies applied to solve the exam problem.

3.1 Midterm exam

Students were asked to obtain an axonometric view of an object from its orthographic projections, without hidden lines and using three different methods: 1) through the use of classic drawing instruments, 2) through 2D computer delineation, and 3) through 3D modelling. The mental recognition of a 3D object from its orthographic views involves the use of spatial vision capacity. The orthographic projections were presented to students using top, front and profile views according to the first-angle projection scheme (Fig. 1). The modelling of this object requires the use of a variety of modelling operations that all lab groups have seen in their respective classes with the same level of detail. Dimensions could be obtained directly from the grid embedded in the drawing (5 mm distance between lines).

Figure 1. Orthographic views of the proposed object.



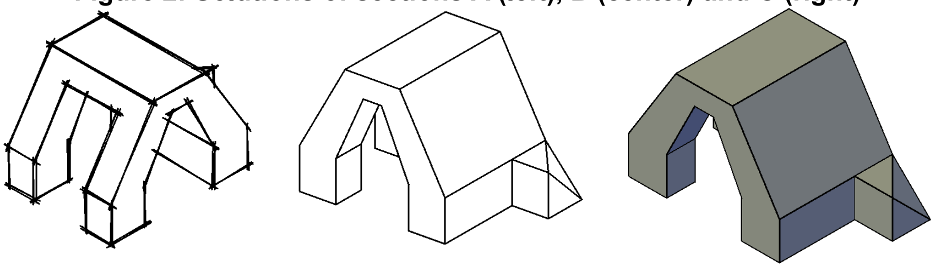
As previously commented, the exam consisted of three sections, each of them was scored between 0-10 according to different assessment criteria: correct orientation (33.3%), correct proportions (33.3%) and correct lines (33.3%).

In section A, students were asked to draw an isometric view with front-left-up orientation. Students could use a paper isometric template and sketch the drawing by hand. Solution is presented in Fig 2 (left).

In section B, students were asked to obtain an axonometric view with front-right-up orientation, with axonometric angles of XOY= 105º, XOZ = 70º and YOZ = 120º and axonometric scale E_x=1.0, E_y=1.0 and E_z=1.2. The solution had to be implemented with the CAD tool within the 2D environment, it is presented in Fig 2 (center).

In section C, students had to represent an isometric view with free orientation (a possible solution is showed in Fig 2 right). The solution had to be implemented with the CAD tool within the 3D environment. In this section the assessment criteria depended on the correct modelling operations included in the isometric view (total of 4 modelling operations).

Figure 2: Solutions of sections A (left), B (center) and C (right)



3.3 Online questionnaire

After the exercise, students were asked to answer a questionnaire about their opinion of the three methods proposed as well as their opinion about the usability of the CAD tool to perform this kind of exercise. The participating students signed electronically a data protection agreement. This document showed the questionnaire's purpose and explained that teachers assure confidentiality and protect the personal data handled.

The survey consisted of four main blocks.

1. The first one helped to characterize the basic traits of the people who took part in the study (mail, gender and Laboratory group).
2. The second block extracted information on the general opinion about the exercise proposed. Some of the questions formulated in this block were about the difficulty and the speed of completing each section and the possible reasons.
3. The third block was related to a usability study. The System Usability Scale (SUS) was invented by John Brooke (1996 & 2013), since then it has been tried and tested, and it has proven to be a reliable method to evaluate the usability of the systems compared to industry standards. It consists of a 10-item questionnaire with a Likert scale. Participants rank each question from "strongly agree" to "strongly disagree". These responses are subsequently translated into a numerical score, so "strongly agree" means 5 points and "strongly disagree" 1 point. Then, a usability score is obtained in the range of 0-100. The results do not represent a percentage, but a score to measure the level of usability when users interact with the CAD 3D tool. With a score of 80.3 or higher, users express their full satisfaction with the use of the CAD tool. If the score is less than 51, the tool should be redesigned.
4. The last one was related to the general opinion about the use of the CAD tool in contrast to the classical methodology (with classic drawing instruments) in order to obtain axonometric views from an object.

Questions of the survey are shown in Table 1.

Table 1. Questions of the students' survey.

Aim	*Question*	*Possible answer*
To know the profile of students	Name and Surname	Open answer
	Gender	Male Female Other
	Laboratory group	LA1 LA2
To know the difficulty and speed of completion of the exercise	Rate the difficulty of each of the three sections (A, B and C)	1. Very easy/ 2. Easy/ 3. Neither easy nor difficult/ 4. Difficult/ 5. Very difficult
	Rate the speed of completion of each of the three sections (A, B and C)	1. Very fast/ 2. Fast/ 3. Neither fast nor slow/ 4. Slow/ 5. Very slow
To know the reasons about the difficulty of each section	Considering the section (A, B or C) that you found most difficult, indicate the possible reasons:	I am not proficient enough with the CAD tool (AutoCAD) I need to train my spatial vision capacity more Due to my lack of theoretical concepts of Technical Drawing I have not practiced similar exercises at home (or I have done very few) Others (open answer)
	Considering the section (A, B or C) that you found least difficult, indicate the possible reasons:	Thanks to my experience with the CAD tool Thanks to may spatial vision capacity Thanks to my theoretical concepts of Technical Drawing Thanks to the hours I have been at home doing similar exercises Others (open answer)
SUS study	I think I would use this CAD tool frequently	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I find this CAD tool unnecessarily complex	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I think the CAD tool is easy to use	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I think I would need help from a person with technical knowledge to use this CAD tool	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	The functions of this CAD tool are well integrated	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I think the CAD tool is very inconsistent	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I imagine that most people would learn to use this CAD tool very quickly	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I find that the CAD tool is very difficult to use	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I feel confident in using this CAD tool.	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	You need to learn many things before being able to use this CAD tool.	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
To know the General opinion of the use of the CAD tool vs classical methodology	The use of the CAD tool has allowed me to better understand the model	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I consider easier for me to represent axonometric view from the 3D model than if this information is requested by hand and on a paper sheet	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree
	I consider that my skills in interpreting views and visualization skills improve with the use of the CAD tool.	1. Strongly disagree/ 2. Disagree/ 3. Neither agree nor disagree/ 4. Agree/ 5. Strongly Agree

4. Results

4.1 Midterm exam

A total of 27 students participated in the midterm exam, of whom 11 were women and 16 were men. Section A was handed over to the teacher on paper. Sections B and C were submitted to the Virtual Classroom in independent files. 10 of the 27 students (37%) submitted their solutions for sections A, B and C. Another 8 (29.3%) submitted sections A and C. 5 (18.5%) submitted sections A and B, and 4 students (14.8%) only submitted section A. Table 2 summarises the results obtained in each section. In order to compare scores obtained in each of the sections assessed, all scores were scaled from 0-10.

Table 2. Summary of results obtained in each section.

	Section A	*Section B*	*Section C*
N	27	15	18
Mean score (M)	6.20	3.33	6.37
Std deviation (SD)	2.23	2.53	2.58
Std error (SE)	0.43	0.65	0.61
Min score	1.67	0.17	1.00
Max score	9.00	7.67	9.33

Shapiro-Wilk test showed that the scores of each section could be considered normal distributed. Therefore, an ANOVA analyses was applied and showed that there are significant differences between the scores of the sections $F(2, 57) = 8.38$, $p = 0.001$.

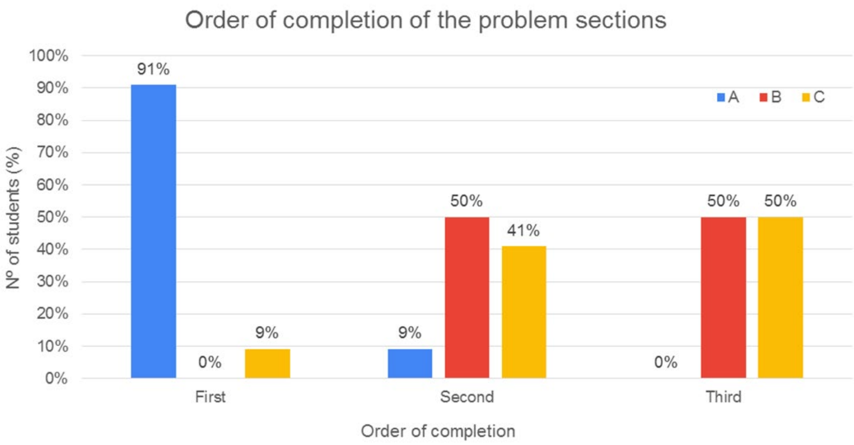
The pairwise comparison between sections, using the Bonferroni test, indicated that the mean score for section B was significantly different from sections A and C. However, mean score of section A did not significantly differ from section C.

In the light of the results, sketching and 3D modelling methods scored better than the 2D computer delineation. They also obtained more submissions than section B of 2D computer delineation. It seems that the exercises proposed during the theoretical classes to solve by hand have improved students' skills with classical drawing instruments. We hypothesise that once the students understand the shape of the part from its orthographic projections, it is easier for them to create the 3D model first to obtain the axonometric view later, rather than work directly in a 2D CAD environment.

4.2 Online questionnaire

Of the 27 students who took the exam, 22 of them answered the questionnaire. Of these, 10 were women and 12 were men.

Figure 3: Order of the completion of the sections.



As Figure 3 shows, 91% of the participants completed firstly the section A while sections B and C were similarly selected as the second or third option.

Figure 4 and 5 show the difficulty and speed of each section, according to the students' opinion. Section A (classical methodology) was considered as a slow/neutral method and easy to complete it (45% of students considered this section as very easy or easy). Section B (2D computer delineation) was considered as very slow/slow method (68%) and also difficult or very difficult to be performed (50%). Finally, section C (3D CAD) was considered as fast or very fast (54%) but difficult (45%) to be performed, but less difficult than section B.

Figure 4: Order of the completion of the sections.

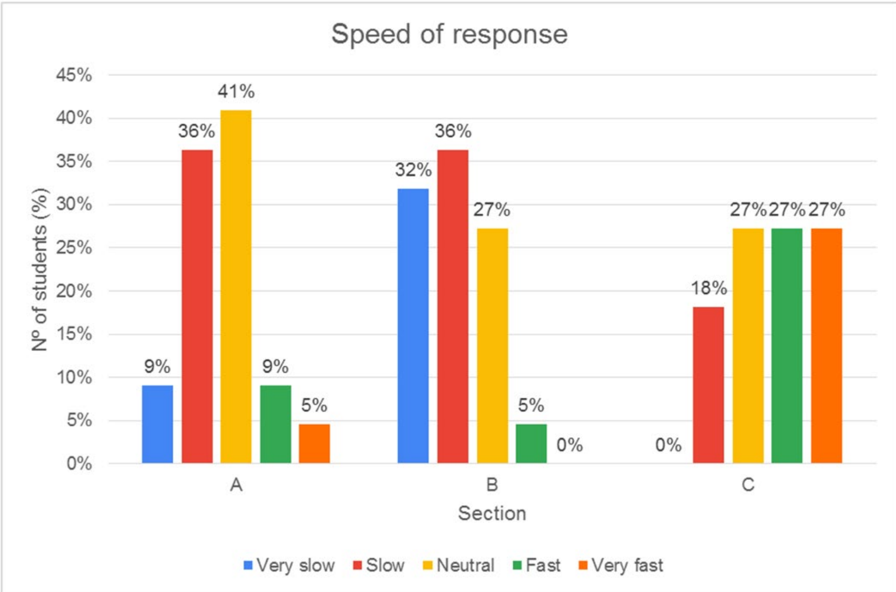


Figure 5: Order of the completion of the sections.

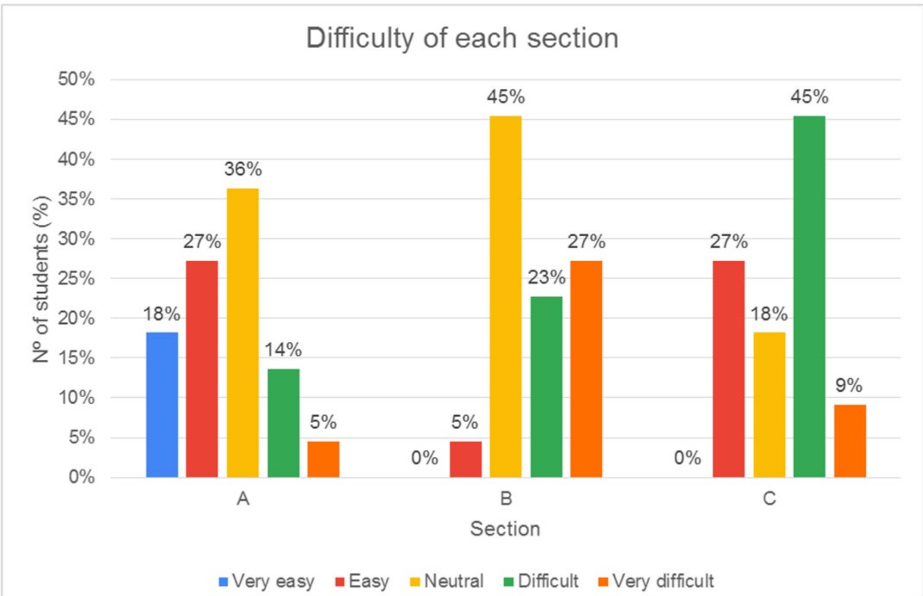


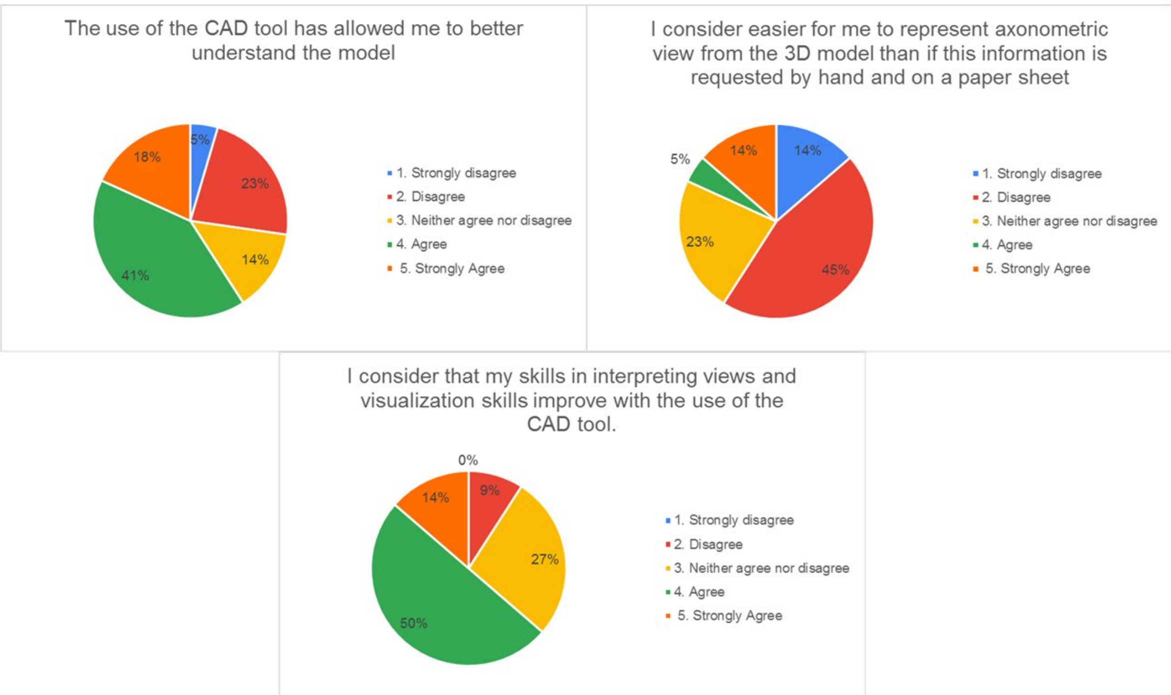
Table 3 presents a summary of the reasons about the difficulty and easiness of the sections (two questions, first column) and the answers obtained (second column). Answers are described by their relative frequency (third column).

The results show that 63% of the students believe that the difficulty of the exercise (mainly sections B and C) is due to the need to train more their spatial vision (33%), as well the necessity of more training with the CAD tool (30%). On the contrary, 76% of the students believe that the reasons for which section they found easier (mainly section A) could be due to the hours they spent at home doing similar exercises (40%), as well as their better spatial vision (36%).

Table 3. Questions and relative frequencies in answers of the second block.

Questions	*Answers*	*Rel. Freq.*
Considering the section (A, B or C) that you found more difficult, indicate the possible reasons:	I am not proficient enough with the CAD tool (AutoCAD)	30%
	I need to train my spatial vision capacity more	33%
	Due to my lack of theoretical concepts of Technical Drawing	13%
	I have not practiced similar exercises at home (or I have done very few)	13%
	Lack of time.	10%
Considering the section (A, B or C) that you found easier, indicate the possible reasons:	Thanks to my experience with the CAD tool (AutoCAD)	16%
	Thanks to my spatial vision ability	36%
	Thanks to my knowledge of theoretical concepts of Technical Drawing	8%
	Thanks to the hours I have been at home doing similar exercises	40%

Figure 6: General opinion of the CAD tool.



After collecting the scores given by the participants in the SUS analysis to measure the usability of the website, the correspondent calculation is applied. The average score obtained is 63.63. This means that users define the CAD tool as a useful resource; however, it can still be improved or other CAD tools can be used to resolve this kind of exercise.

Finally, and in general, the participants consider that the CAD tool is useful in terms of understanding the model, interpreting views and improving the visualization skills (reflected by 59% of the polled people (Figure 6 up-left and down)). However, participants do not consider the CAD tool useful to represent axonometric views, compared to classical methods (59%).

5. Conclusions

During the first part of the Graphic Expression subject in the first course of Agrifood Engineering and Rural Environment degree, students are introduced to multiview projection and axonometric projection by using classical drawing tools and a CAD application (particularly AutoCAD, in both 2D and 3D environment).

To compare the efficiency of these three methods, a midterm exam was conducted where students had to represent axonometric views from an object applying each method. The paper also describes a questionnaire addressed to know the students' opinion after the midterm exam and evaluate the usability of the CAD tool (AutoCAD) in contrast to the classic drawing tools.

Results show that students solved axonometric projection better using the classical method and 3D modeling than using the 2D environment of the CAD tool. These results are consistent with the opinions collected in the questionnaire, which reveal that students consider the classical method easier and 3D modelling faster to work.

The responses to the questionnaire also highlight that most students perceive that 3D modeling improves their spatial vision, although they still think it is a difficult task. We can conclude that this last perception is related to the fact that students admit that they took more time working with sketches than with the CAD application.

The 2D delineation method had the lowest score, and students consider it a slow and difficult method. Obviously, this method implies taking into account various aspects such as the axonometric scales and the axonometric angles. These aspects are not relevant to sketches or isometric views, which are automatically projected from a 3D model.

The SUS test reveals that students value the usability of the CAD tool to solve these types of exercises, as teachers, we consider that this test could increase its score if students improved their skills with the CAD tool. This point is supposed to be reached at the end of the course.

We conclude that the three methods contribute differently to the achievement of the objectives and competences of the subject. The freedom of sketches allows to obtain quick and approximate solutions. 3D models improve spatial vision in students. The 2D delineation method allows for accurate solutions and a wider range of axonometric (not just isometric) views, but it also requires a major effort and time for students.

Acknowledgements

This work has been funded by the "Universitat Jaume I"; through project 3810/20 within the Innovative Education Project titled: “Introducción de nuevas metodologías docentes para mejorar la capacidad espacial del alumnado y aumentar su participación en el aprendizaje en la asignatura de Expresión Gráfica”.

References

Brooke, J. (1996). *SUS: A “quick and dirty” usability scale*. In: Jordan, W., Thomas, B., Weerdmeester, B. A., McClelland, A. L. (eds.), Usability Evaluation in Industry. London: Taylor and Francis.

Brooke, J. (2013). SUS: A retrospective. *Journal Usability Studies 8(2)*, 29–40.

Clements, D., & Battista, M. (1992). Geometry and spatial reasoning. In *Handbook of Research on Mathematics Teaching and Learning* (A. E. Kelly, & R. A. Lesh), 420-464, New York: Macmillan Publishing Company.

McGee, M. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences, *Psychological Bulletin, 86*, 889-918.

McGrath, M.B., & Brown, J.R. (2005). Visual learning for science and engineering, *Computer Graphics and Applications IEEE, 25(5)*, 56-63.

Plumed, R., & Gómez-Fabra, M. (2016). *Apuntes de Expresión Gráfica*. Spain: Universitat Jaume I. Retrieved from: http://hdl.handle.net/10234/151825.

Plumed, R., González-Lluch, C., & Gómez-Fabra, M. (2018). Use of gamification to perform an initial evaluation of students in the subject of Engineering Graphics. In *10th International Conference on Education and New Learning Technologies, EDULEARN18 Proceedings*, 7756-7761.

Smith, I. (1964). *Spatial ability: Its educational and social significance*. London: The University of London Press.

Ye, X., Peng, W., Chen, Z., & Cai, Y. (2004). Today’s students, tomorrow’s engineers: an industrial perspective on CAD education, *Comput. Des., 36 (14)*, 1451–1460.

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