

**AC 2008-124: TEACHING PART VISUALIZATION IN FIRST YEAR
ENGINEERING COURSES: GENERAL SCHEME FOR PART VISUALIZATION
PROBLEM SOLVING**

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Teaching Part Visualization in First-Year Engineering Courses: Methodology for Part Visualization Problem Solving

Abstract

Part visualization is a fundamental skill in engineering. It refers to reading and understanding any technical drawing, interpreting different views of an object/assembly which has been represented on a standardized drawing. However, engineering students show certain learning difficulties and a high failure rate in subjects such as Technical Drawing and Design. The main aim of this study is to introduce a new teaching strategy for part visualization.

A problem solving model for visualization has first been designed for all kind of industrial objects (Methodology for Part Visualization Problem Solving) with a constructivism view. Teaching strategies may then be applied by drawing up a programme of specific tasks which takes into account the theoretical contents and procedures involved in part visualization and students' main difficulties and deficiencies when solving this kind of problem. ICTs (Information and Communication Technology) and real models have been used in classroom to help the students link the 2D drawing with the 3D object/assembly.

After testing the method in the classroom, the results which have been obtained from experimental and control groups test have been contrasted, showing an important improvement (fewer drop-outs and a higher percentage of students who have passed the course).

In terms of comprehension of part visualization, the percentage of students who have passed the specified exams has been higher than the control group and the average grade has been higher as well. It is worth noting that every student has an improvement of 10% on their grade in the comparisons made between the first visualization quizzes and last ones completed in the first trimester.

These positive but not statistically significant results encourage us to keep improving the teaching-learning process of the part visualization.

This study has been done in the first course of Industrial Engineering in the Faculty of Engineering of Bilbao in the The University of the Basque Country. The subjects of the study have been selected randomly and the students do not know that they have been part of a study.

Why this intervention?

There are three main reasons that justify this didactic intervention:

In the subjects of engineering, difficulties are observed in the visualization of parts and the development of spatial capacities throughout the course (Sierra Uria, Egoitz, 2005)¹.

The ability to mentally visualize and manipulate objects and situations is an essential need in many jobs and careers. It is estimated that at least 84 majors consider the spatial visualization a fundamental need (Smith, 1964) and in technical jobs, such as the different types of engineering, the abilities to visualize are especially important (Maier, 1994)².

The third reason that justifies this study is that educators need to continually analyze and investigate their own teaching to be more effective educators (Fernando Hernandez, 1992)³.

Previous analysis and current situation

The visualization of parts in the multiview projections system, in other words, the interpretation of views of an object represented by its technical drawing, is a fundamental skill in the engineering career, and in the learning of the Technical Graphic subject, because if a student is unable to visualize, then he/she will not be able to continue mastering the rest of the content of the subject.

It is necessary to analyze the specific difficulties that arise in the learning of visualization. Educators have often noticed the difficulties of most students in graphic courses when trying to visualize an object using multiview drawings. This is mainly due to the inexistence of a systematic process to analyze complex forms (Luzzader y Duff 1986)⁴.

We also find students that haven't developed their spatial capacity enough and therefore have serious difficulty understanding and manipulating the parts in space (Navarro,2004)⁵. One of the main causes could be the didactic strategy followed in most classrooms, which consists of visualization problems followed by the solutions to those problems, without explaining how to solve them or the reasoning needed during the problem-solving process (Garmendia, 2004)⁶. The students confirm not having a problem-solving strategy, and that they use the trial-and-error strategy instead or they rely on intuition.

On the other hand, a review of the literature of technical drawing textbooks has not been successful in finding a clear, concise, and developed method of solving visualization problems using procedural contents. Sierra Uria, Egoitz, 2005¹.

Even the most advanced engineering students in other subjects, encounter difficulties comprehending the mechanisms that relate the representation of three-dimensional objects to their reality (Pérez Carrión y Serrano, 1998)⁷. Students affirm comprehending the theoretical aspects but they have trouble with procedural techniques and reasoning while solving visualization problems.

In this sense, this didactic study in problem-solving affirms that when students reason, different aspects of inter-related knowledge are put to work. A set of general abilities is used and applied to concepts of a subject, creating particular ways of reasoning in that subject. Therefore, the didactic study affirms that, besides the theoretical and conceptual knowledge, another content such as procedural knowledge must be considered in teaching (Guisasola et al. 2003)⁸.

This study proposed a problem-solving model⁹, adapted to the case of object visualization, integrating resolution structure, concepts, procedures and different types of reasoning specific to visualization.

Didactic research provides evidence, even more so in recent years, of the inefficiency of conventional teaching methods. The notion that the knowledge of the professor can be transmitted in its final stages (by stating a problem and showing how to solve it based on the solution) is not the best way to help the students' learning process. Teaching scientific knowledge in the final stages in an organized manner does not prevent failure in learning concepts and problem solving. (Maloney 1994)¹⁰.

When planning the teaching of specific content and deciding the design of the learning process through an activity program, it is necessary to define certain aspects. Among these, the intended objectives and the contents, keeping in mind the possible difficulties that can arise in the assimilation of the content by learners. But at the same time, it is necessary to define the strategy that will be followed to improve the meaningful learning, defining a logical sequence of activities designed expressly for the learning process, as well as the type of assessment that will be used to improve and orient the learning.

On the other hand, another factor related to the visualization of parts is the spatial capacity. Mathewson (1999)¹¹ affirms that educators often forget the factor of spatial-visualization in learning. A review of most of the text books in the subject show that little is done to improve the development of the spatial capacity. The engineering textbooks present often orthogonal views, static concepts, theories and ideas with little or no explanation, and no interpretation of spatial data. It is assumed that the student will be able to overcome the mental challenge, assembling the spatial puzzle.

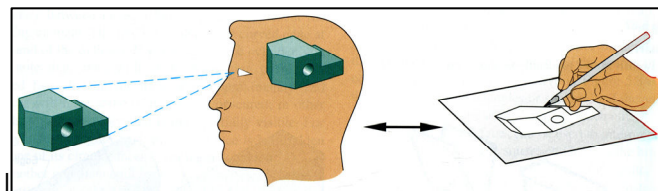
Currently the ICTs (Information and Communication Technology) offer complementary tools for the learning of every subject, therefore, for the visualization of parts. Agreeing with Bertoline et al. (1995)¹², one way to improve the ability of the student when

visualizing an object or a 3D scene is to make his/her experience as realistic as possible. The ICTs have permitted the apparition of new working tools, such as the VRML (Virtual Reality Modeling Language) or the X3D, that enable the interaction with objects through a virtual world, lowering the difficulties of comprehension between the spatial reality of a part and its representation on the technical drawing.

As Mc Lellan affirms (1998)¹³, virtual reality is a cognitive tool that permits the immediate dynamic interaction, making it possible for the student to comprehend the engineering concepts that are spatially dependent.

According to a number of authors, in order to increase the spatial capacity it is necessary to work with 3D models in space wich can be turn, move, and work on mentally, for example by obtaining their projections (Devon et al. 1994)¹⁴

According to Potter (2003)¹⁵ the students with a deficient development of spatial capacity, need to learn, by using static, dynamic and transformational images, as well as their combined use in problem solving. The spatial perception can be developed in many ways, including: modeling and freehand drawing of objects, representing objects in 3D models, manipulating objects in 3D, in order to recreate their representations dimensionally, finally experimenting and working with different perspectives or views of the represented part or object both on the blueprint and in the computer image.



Bertoline, 2003¹⁶

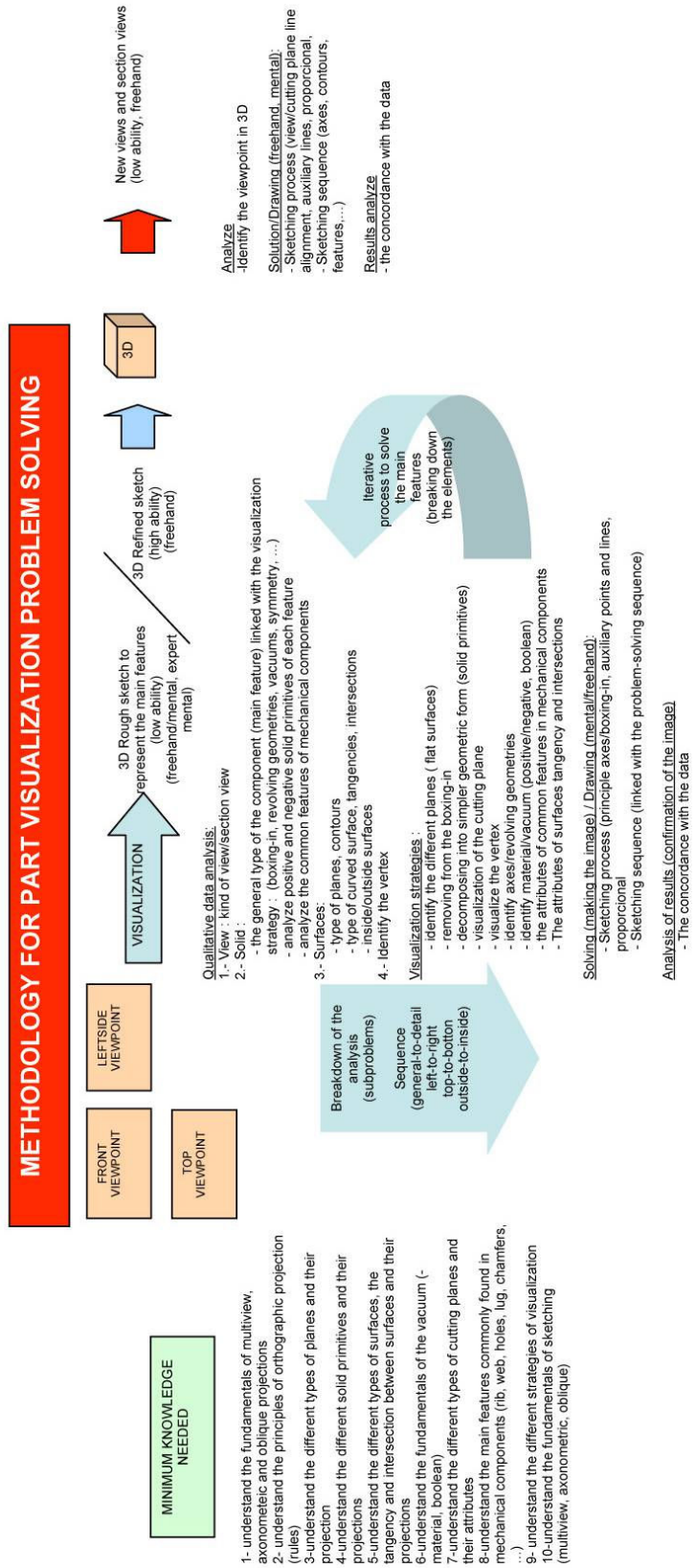
As Wolfram(1994)¹⁷ writes, people only remember 15% of what they hear, and 25% of what they see or watch, but they do remember 60% of what they interact with. Therefore, educators in engineering schools should start using interactive multimedia tools in their curricular content.(Mohler,2001)¹⁸

Intervention characteristics

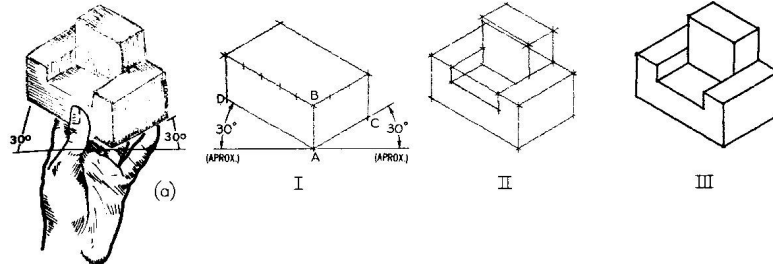
The intervention was conducted under a constructivist focus and under the European frame of higher education, and was characterized by the following:

- Basically the problem-solving process was used to solve visualization problems, working on the PROCESS (avoiding problem-solution)

Methodology for Part Visualization Problem Solving

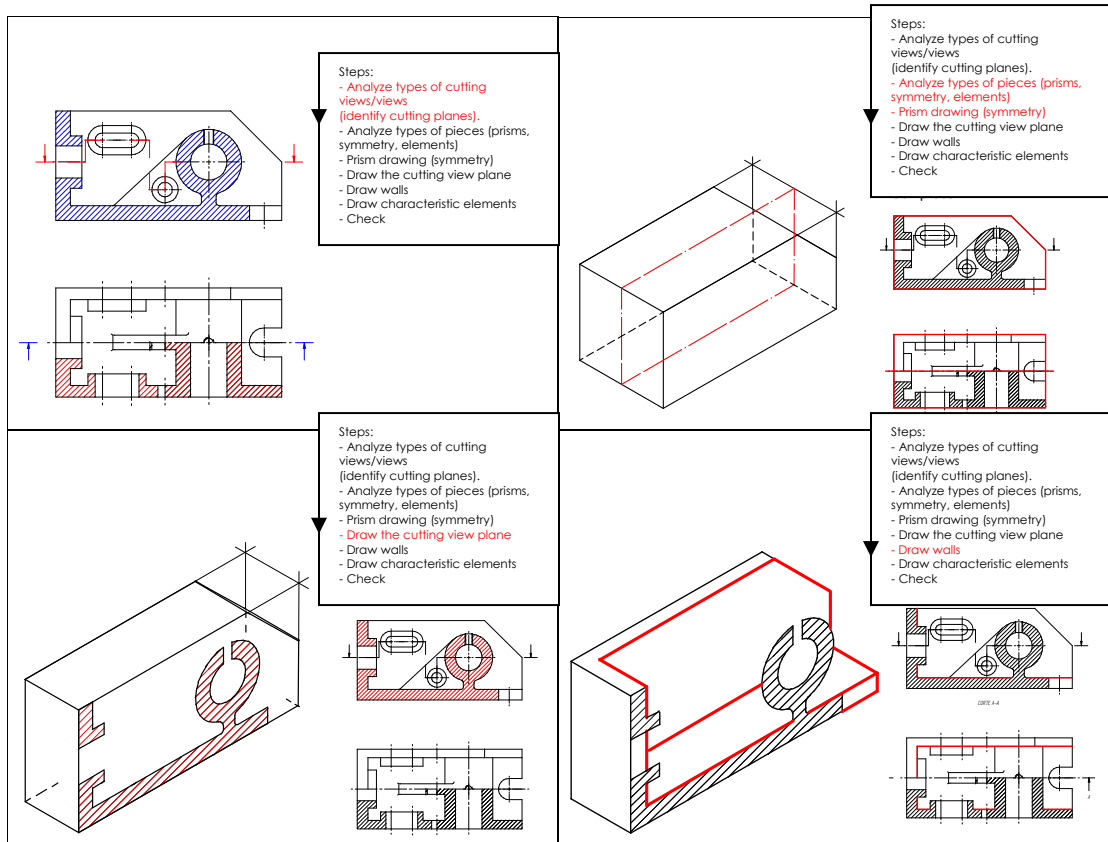


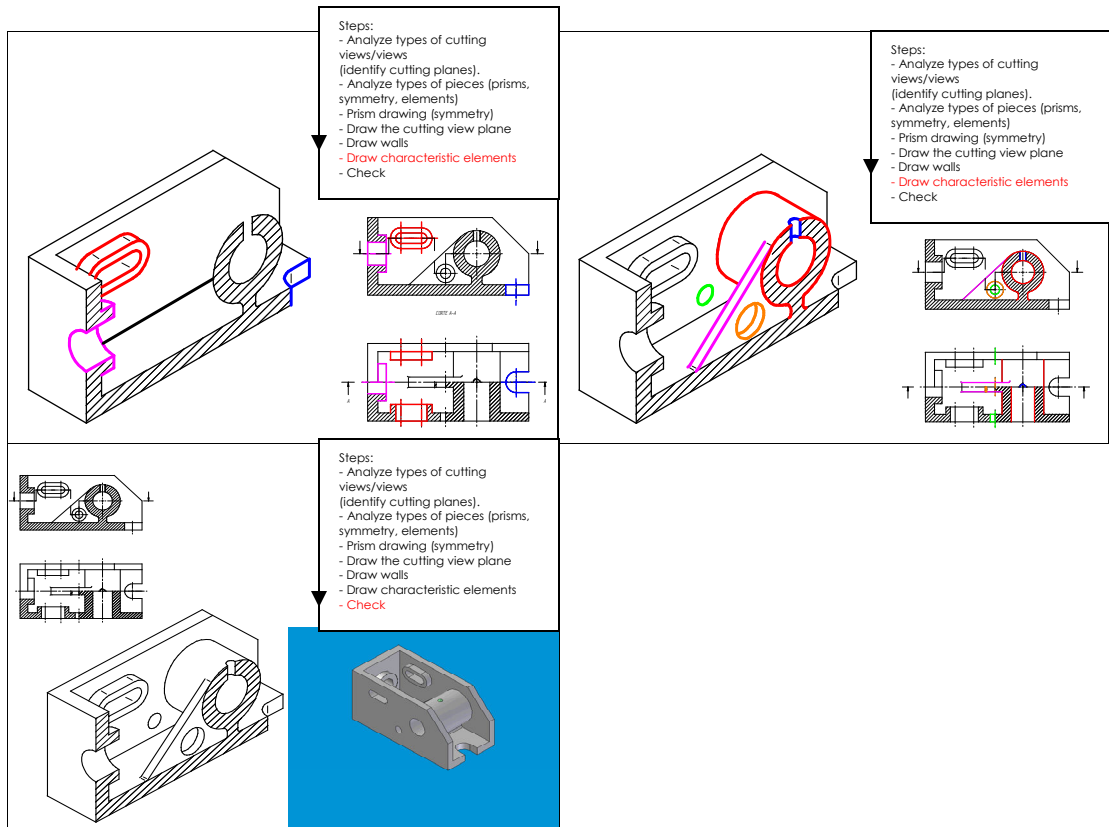
- Sketch: Sketching is used explicitly because it is a very important and a necessary capacity and as a means to double check what has been visualized.



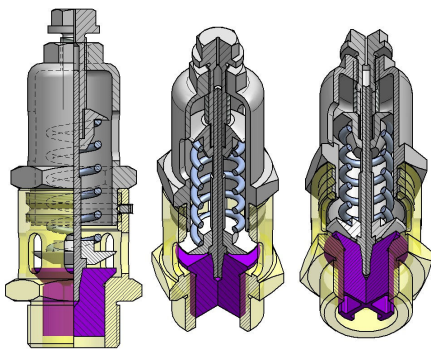
Sketching process. Giesecke, Spencer , 1987²⁰

- Solution strategies: Different solution strategies have been developed according to the types of parts and/or data provided.

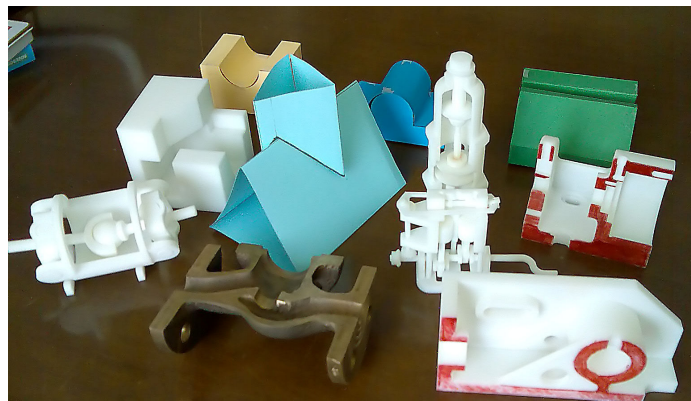




- Supplemental materials (ICTs and other): Projector (3D model visualization) and physical models in 3D(prototyped parts and carton models).



Virtual models



Physical parts and models

- According to the European Frame work: Subject planning and its working method, both have been designed under the European higher education framework. ECTS credits, student's individual work, weekly work, continuous evaluation.

Graphic Expression Subject competencies

1	See in the 3D space
2	Read, interpret and create a standardized drawing
3	Communicate in graphic language
4	Graphical problem solving
5	Graphic knowledge industrial application

Functioning of the subject

Type of work	Competency	Classroom (hour/week)	Housework (hour/week)	Material Resources	Evaluating tools
Theory work in the classroom (thematic unit 1)	All	2 *(1)	0,5	Board+ projector +PC	Drawings and test
Individual theory work (thematic unit 1)	2, 3, 5		1 *(2)		Drawings and test
Applied work Classroom (Problem	All	2	4	Board+ projector +PC	Drawings and test

solving)					
Office hours				Office	
Group office hours	All	2 * (3)		Board+ projector +PC	VOLUNTARY
Partial assessment Exam	All	10hours/year			Test
* (1) * (2) * (3)	<ul style="list-style-type: none"> - Thematic Unit I to be developed in class (in place) - Theamtic Unit II to be developed by the student (not in place) - Voluntary (doubt resolution in groups) 				
Assessment	<ul style="list-style-type: none"> - Class grade: Weekly drawings - partial exam (minimum grade 3,5) 			30%	70%

- The subjects of the study were selected randomly. First year Industrial Engineering consists of six classes and the students were assigned to each depending on their study language (Basque or Spanish) and after that by alphabetical order. Each group has a professor and exams are the same for all groups. The experimental group was one of those groups and students did not know that they were part of a study.

First results

In the following tables the first results obtained are shown:

Table 3: Data from the first intervention (Industrial Engineering 06/07)

	Experimental group	Control group	Differences
Class size	46	309	Homogeneous groups
Test 1 Average (/45) ¹⁹	22,93	21,74	

Previous knowledge	90%	89%	Homogeneous groups
Present at the partial test	46	256	
Present at the partial test (%)	100%	82,84%	Higher attendance, 18%
Average visualization exercise			10% higher
Number of passing visualization exercises	36,95%	23,82%	More passed, 13%
Test 2 Average (/45) ¹⁹	29,68	27,65	minimum improvement 4%
Improvement Test 2 Average	15%	13,14%	Both improve >12%
Attended private classes at the end of the semester	18,18%	35%	Less necessity 17%
Attended test	40	231	
Attended test(%)	86,95%	74,75%	Higher attendance, 12%
Average visualization exercise			5% higher
Passed visualization exercise	20%	12,55%	More passed, 7,45%

Table 4: 2nd intervention data (Chemical Engineering 06/07)

	Experimental group	Control group	Differences
Class size	29	32	
Test 1 Average (/45) ¹⁹	14,7	14	Homogeneous groups
Previous knowledge	42%	38%	Homogeneous groups
Present at the partial test	22	20	

Present at the partial test (%)	86%	62,5%	higher attendance, 21%
Average visualization exercise			8% higher
Number of passing visualization exercises	28%	25%	More passed, 3%
Test 2 Average (/45) ¹⁹	20	18	minimum improvement 2%
Improvement Test 2 Average	12%	9%	Both improve
Attended private classes at the end of the semester	14%	25%	Less necessity
Attended test (%)	58%	53%	Higher attendance, 5%
Average visualization exercise			4% higher
Passed visualization exercise	38%	34%	More passed, 4%

Conclusions and possible future studies

Most data show an improvement in the experimental group and better results in regards of assessments such as student's work and tests. We analyzed data qualitatively and not quantitatively, for this reason we consider no need of statistical analysis per se. The statistical analysis is not the aim of this study, the main aim of this study is to introduce a new teaching strategy for part visualization.

- The average grade has been higher in the experimental group as well as the number of passing students, therefore there has been an improvement in the teaching-learning process.
- In the experimental group the percentage of attendance has been higher; therefore the number of students who drop the course is lower. Thus this intervention has motivated the students and has permitted more students to follow the teaching-learning process.

- The percentage of students that have attended private lessons is lower in the experimental group. This means that the university has provided the necessary knowledge and resources to follow the course and teach the subject in a better way than using traditional methods.
- As this is the first year of intervention, results are hopeful but upcoming interventions should be improved upon so that results are more conclusive and the methodology is accepted and widespread.

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