



Visual literacy for Engineering Education

Competence Framework

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The VLEE PROJECT

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This Guide supports HE institutions, VET trainers and institutions as well as stakeholders in the implementation of the Visual Literacy Competence Framework (VLEE).

The list of examples provided in the Guide's aims to illustrate the wide range of VLEE implementation.

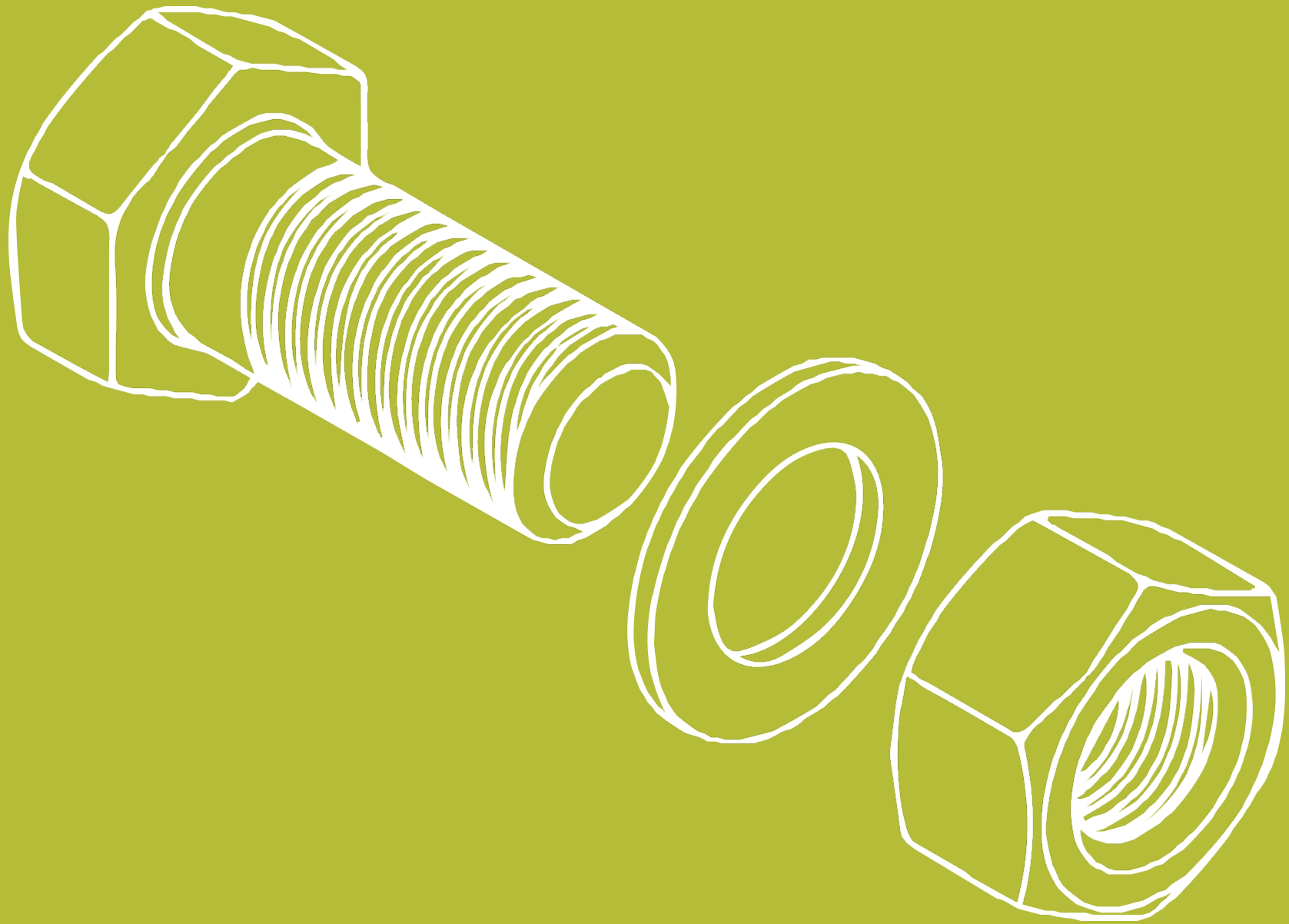
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Guide to the

Visual Literacy
for
Engineering
Education

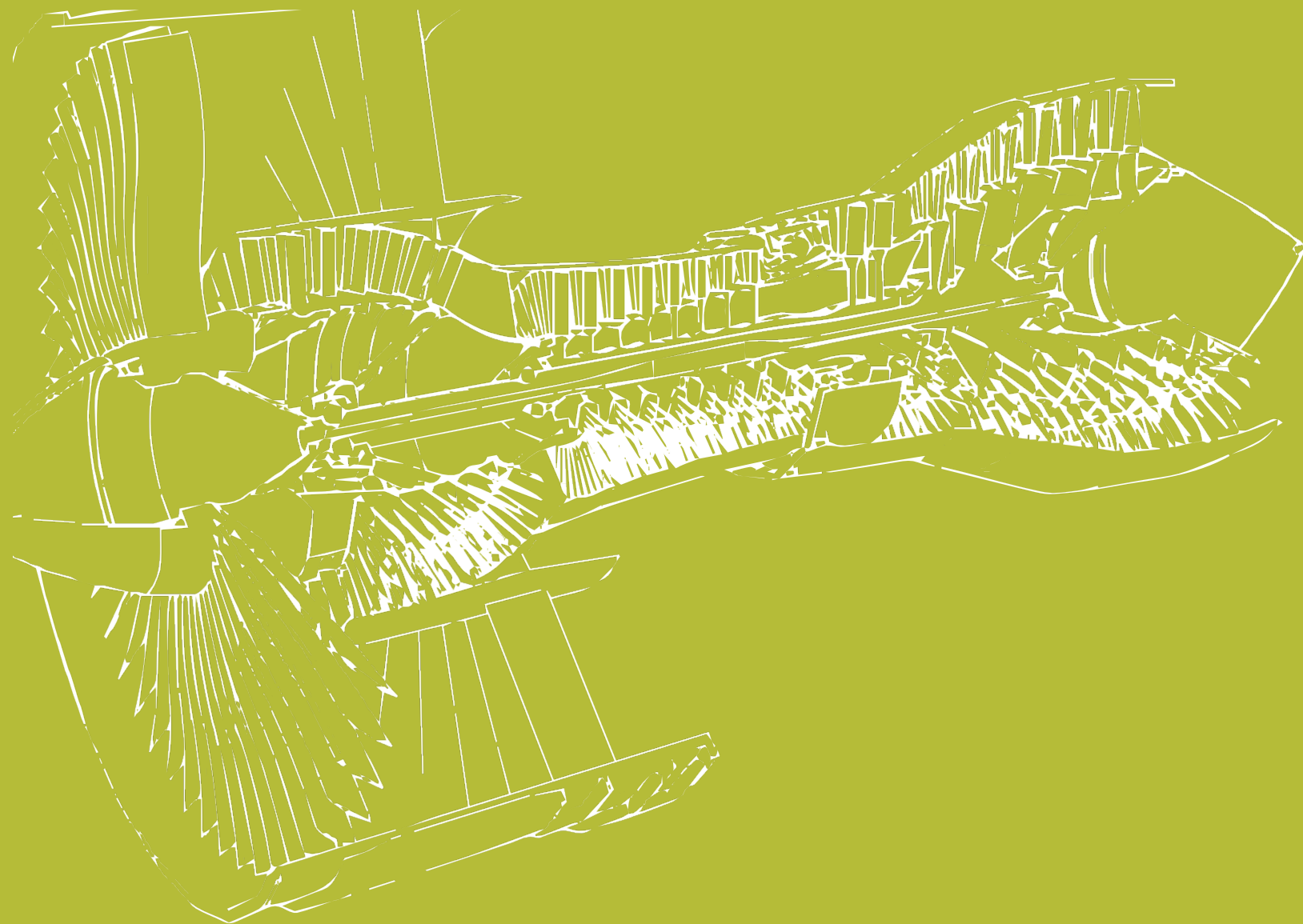
**Competence
Framework**





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Introduction

The significance of images and visual media in 21st century has an impact on the meaning of being literate. Television, advertising and press shows the great amount of visual materials used currently for communication. Digital technologies also accelerated the importance of images as a ways of communication in all domains. In the case of engineering, Graphic and Visual information involves all processes, since the statement of a technical problem to the presentation of the solution. In particular, digital devices in recent decades changed the involvement of engineers in visual communication. They must therefore develop the set of skills and knowledge to move in the technological environment, dominated by visual resources.

However, the importance of visual materials in engineering does not mean that engineers are well prepared to critically use, think and create visually. Current education curricula in engineering takes partially this need of having students visually literates. Educators require a set of competences to get future engineers the means to cover these needs.

This guide presents a framework for the development of Visual Literacy competences required for engineers and technicians. Its objective is to provide adequate resources to develop their Visual Literacy competences and then contributing to the improvement of engineering and VET education. This guide therefore intends to provide a reference for engineering education institutions as well as technology educational programs in general.

This is a concerted effort to structure and communicate the engineering-specific components of Visual Literacy in a way that speaks the language of educators, addressing the specific gaps in their knowledge.

The aim of this framework is to provide a general reference for higher education in the EHEA environment and VET institutions in the same countries. This framework is developed by focusing on the training needs of the Member States of the European Union. It therefore seeks a common reference that can be understood by all of them. VLEE competence framework is a foundation resource enabling educators to quickly engage in knowledge sharing and peer learning about the levels, challenges and opportunities for visual literacies in their respective countries.

The methodology used is strengthened by the conviction that it can be provided an introduction to visual literacy for engineering and its respective competences that is rigorous and based on academic research, but also accessible and practical in nature, so that teaching staff, professional educators and HE/STEM stakeholders can find it directly relevant to the opportunities and challenges they face.

The Visual Literacy for Engineering Education competence framework (VLEE framework) responds to the acknowledged need that visual competences are of great importance for engineers across all disciplines because of the visual involvement of engineering activities, since problem solving to sharing concept designs. It also recognises the interesting possibilities for enhancing the development of Visual skills and abilities thanks to the proliferation of Technologies of information and communication.

The VLEE Framework aims to capture and describe the specific Visual Literacy competences by showing 16 competences structured in 6 areas.



The Framework includes a model that gives support to educators in the progressive development and evaluation of visual competences. The proposed model establishes three different levels through which a visual competence of the student progresses in a gradual way.

At the basic level, engineers and technicians acquire new concepts and start with basic visual and graphic practices.

At the intermediate level they apply, expand and organize such visual and graphic practices.

At the competent level, the engineer is able to transmit knowledge, have a critical attitude and develop new practices in accordance with the competences.

This Framework offers and suggest the revision to the contents of VET and HE engineering educational programs. It is then expected that this competence framework means a motivating element to include in the curricula of Higher education and VET organizations, as well as an element of teaching for stakeholders.

The framework is the result of the work carried out by the VLEE project led by NOT (Poland) and with participating organisations from Denmark, UK, Ireland and Spain.



TÉC TECHNICAL EDUCATION COPENHAGEN

momentum [educate + innovate]



canice consulting



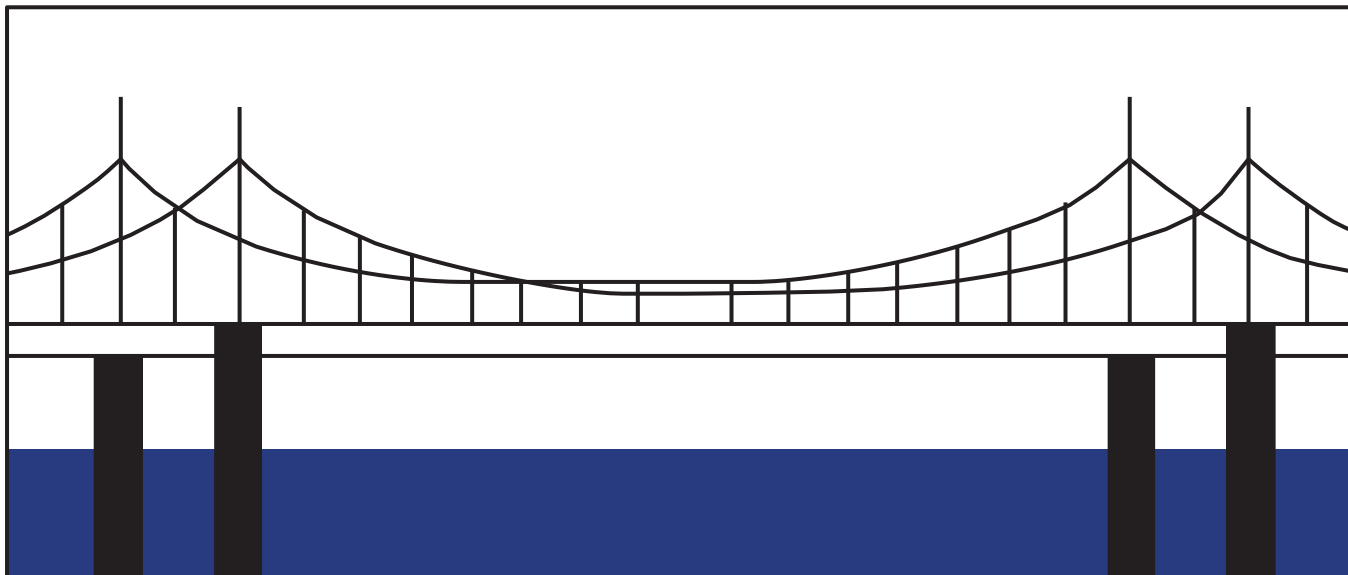


Whose is this guide for?

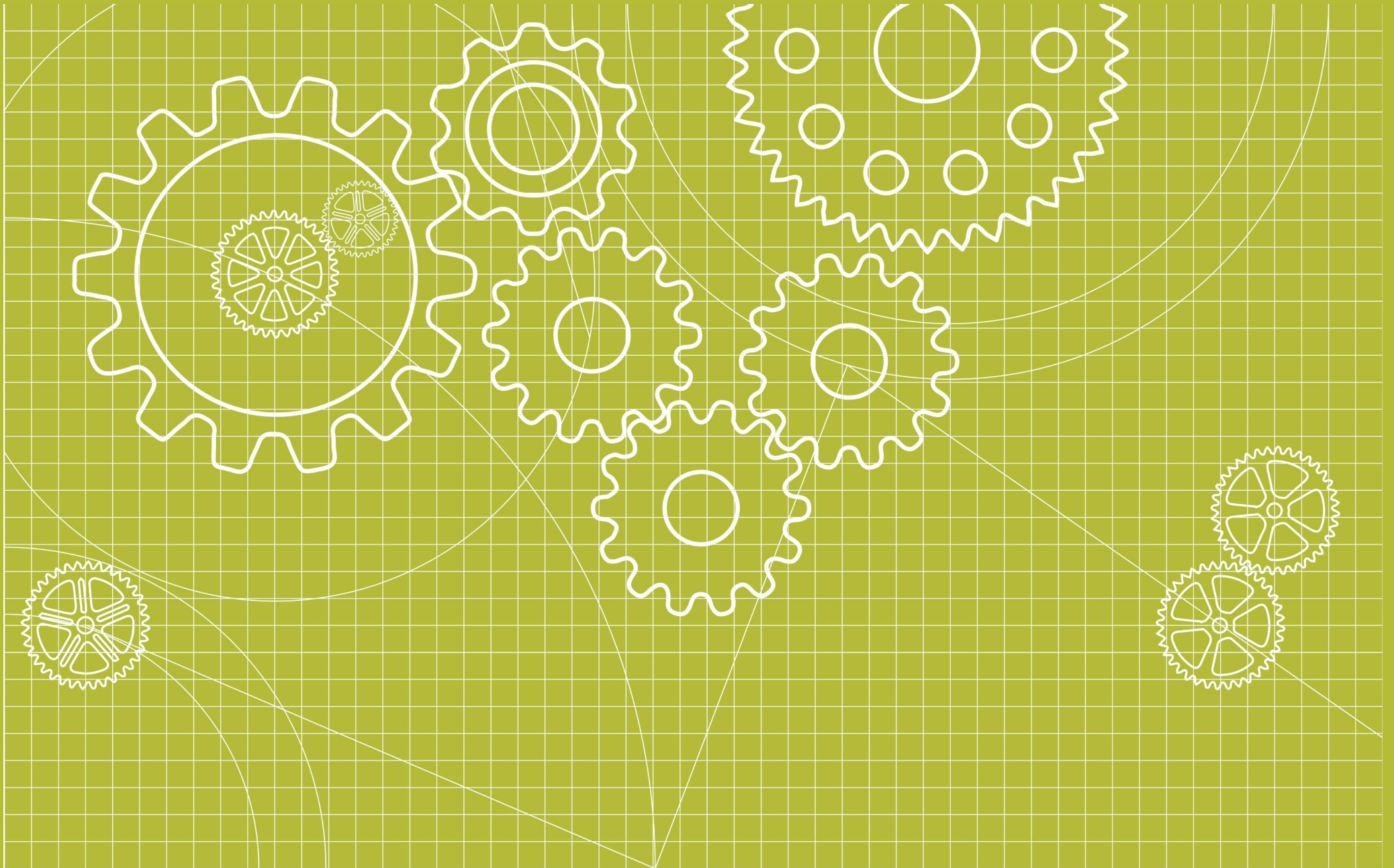
This competence guide is proposed for all those involved in technical tasks, since Higher Education institutions of engineering, VET trainers as well VET organisations as well as professional engineers and stakeholders willing to take new learning initiatives. It is expected that these organizations and institutions as well as stakeholders are motivated to introduce this new teaching initiative.

Visual Literacy practices shall bring engineering and VET students the required skills, abilities and knowledge for enhancing their problem solving capabilities, as well as fostering creative thinking and innovative skills. They also shall become better at communication in a visual environment. The development of Visual Literacy skills is fundamental for future engineers and technicians.

Teachers and trainers will find in this guide up-to-date knowledge to let them how to develop visual competences, becoming more effective at tackling skills gaps among students.



In the same way, Vocational Education and training needs support in renovating their educational methodology as well as using digital technology in ways that better provide to students' learning needs and future performance in the workplace. VET organizations and stakeholders, from technical colleges to professional membership bodies as well as education and business development policy makers will have in this guide a way to better understand the importance of Visual Literacy and how to close the skill gaps observed in the current educational environment. It is expected that the Visual Literacy competence framework means an effective solution to improve the quality of technical education.



The role of Visual Literacy in Engineering

Visual Literacy



A literate person is anyone who is able to read and write texts. It is required for communication as well as for the expression of ideas.

Apart of this, there are other literacies. Specialists mention technological literacy, quantitative literacy (or numeracy), media literacy, digital literacy and Visual Literacy.

Visual Literacy can be defined as the set of skills and abilities to understand, to create, as well as to think and learn using all kinds of visual material, such as images, pictures, and graphics or 3D objects. If literacy is the interpretation and creation of texts, Visual Literacy means the set of abilities that allows the understanding of information, the ideation and communication by visual materials. Visual Literacy needs perfect communication through visual means, which implies interpretation and creation of these.

Apart of communication, Visual Literacy has to do with what we see with the mind, for processing perceived images as well as from our own visual imagery and generate new ones and then to externalize them.

Visual literacy is obviously important in a society crowded with images and other type of visual information.

Visual Literacy is commonly mentioned around the use of images, but it actually involves all types of Visual information, from a freehand Drawing to a mock-up.

A Visual Literate person is anyone able to interpret, to think, to learn and to express using images, pictures, graphics or physical objects. He is proficient in understanding a message from an image, to reason with images as well as to express ideas by using a drawing or a physical model.

The role of Visual Literacy in Engineering

Visual Literacy and Creativity

It has long been recognized that creativity is an essential quality of the successful engineers. Creativity helps in the generation of new ideas and finding solutions to problems. Also, creativity is required for innovation. Innovation is required in industry to face important challenges according to competitive, economical and sustainability matters. To face these challenges, engineers must find valuable and inventive solutions. The best way to achieve this is adopting creative strategies. Everyone has a creative potential which can be nurtured. Since people can be more or less creative, it can be fostered, by applying several pedagogic strategies. One of the best approaches is taking into account Visual perception, Visual Thinking and Visual Expression.

It can be easily shown the advantages of using visuals for creative enhancement. Visual thinking activates the side of the brain which leads us for free ideation. Visual representations allow to see clearly connections between ideas and then have a way to find solutions to problems. When people practice analysis tasks, evaluation of visual inputs enhance their creative potential. Visualization shapes new forms and represents in our mind a new scenario that can become a new and original way to overcome a blocking situation. Visual Literacy also has to do with all these abilities for creativity.

Graphics are the common communication channel in engineering. Along with its function as a means of communication, visual representation is an intrinsic part of the design creative process. A typical case is the exploration of ideas using visuals. That means a process were seeing images, creating them and finally drawing operates in a cycle for finding the solution to a defined problem. Several researchers mention the dialogue between a drawing and the designers, where the sketch “speaks” to him and the designers respond with a new drawing. Visual expression is a key activity in the process of originating new product ideas in engineering. It is understood that a creative approach based on visual means shall be an optimal choice for engineers. Engineering education must be aware of the need teach as well as to practice Visual Literacy being shown to its benefits for ideation and problem-solving skills and innovation competences.

The role of Visual Literacy in Engineering

Visual Literacy in Engineering

Visual Literacy is acknowledged to be of great importance in many professions, commonly in art and design, but also in every domain where visual information plays a significant role. In the case of science and mathematics, Visual Literacy skills are also of most relevance. In engineering it is paramount. Professors Craig L. Miller & and Gary Bertoline stated in 1991 that engineers must be visually literate to be successful engineers.

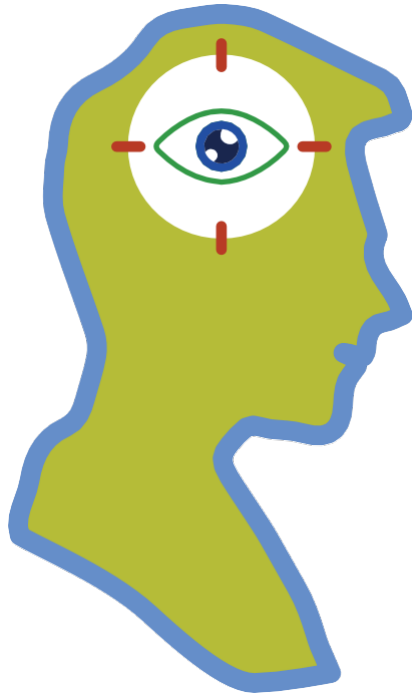
Visual Literacy in engineering is reflected in their work development: engineers are problem solvers who handle a lot of visual information. An engineer requires visual means to express completely the results of their work: a mechanical design or an electronic scheme cannot be defined completely by describing it with words, it requires a pictorial description supported by symbols and annotations, which may be concrete (a mechanical object' drawing) or abstract (an electronic scheme).

Engineers use and produce visuals in all of the technical problem solving tasks, since the identification of the problem to sharing the solution. Engineers need to understand and create messages in visual format as well as to create them to express concepts.

These messages are supported in different formats and abstraction degrees. Since schemes, computer graphics, freehand sketches as well as physical models.

Engineers use a Visual language which is made up of symbols, standardized pictorial representations and annotations. This is how they understand and produce Visual information of engineering. Drawings and sketches reflects Visual Literacy in engineering.

An example of Visual Literacy in engineering is the design intent. How a graphic representation reflects exactly what a design engineers ideated, as well as what an engineer wants to communicate. A set of graphic and text elements are needed to express this idea, so, for achieving that any engineer must be Visual Literate enough to produce this adequate visual message.



One of the most important Visual Literacy skills for engineering is visualization. Being problem solving the main activity of engineering the use of visualization for this purpose is fundamental. To be specific for engineering, visualization means being proficient in handling in mind three-dimensional forms. Spatial abilities are therefore most important.

Other fundamental Visual Literacy skills and abilities are those related to present abstract conceptual ideas graphically, using technical drawing or CAD. These are the skills to draw freehand as well as drafting, and to generate 3D models using computer programs. Visualization is also a required skill in graphic expression as it is necessary to understand projection drawings as well as to generate them.

In that case, engineers apply sketches, engineering drawings, or CADD databases. These are the Visual communication skills specific to engineering. Visual Literacy in engineering involves the use of Visual Thinking, spatial reasoning, the use of 3D modelling, freehand sketching as well as creating physical models.

Visual Literacy in engineering is not only related to the creative side of engineers, but to their analytical tasks. Apart of shapes and functional descriptions of designs, engineers need their visual literacy to express analytical information. They use graphic representation of data in all of the development stages of a product or system, as it is an easy way to explain the results of calculations or empirical data collections. Sharing data by visual means is a key skill for a professional engineer.

Digital technologies and Visual Literacy

The possibilities for developing VLE competences have grown exponentially thanks to the proliferation of digital technology, which has a clear influence on Visual Literacy. The advent of computer graphics, internet video channels, infographics and social media enhanced the range of visual expression and communication.

One of the major changes, as the result of the digital technologies, is the availability of new forms of

communication. Infographics is a visual communication resource mostly common thanks to the web. Their combinations of illustrations, typography, data visualization, maps or schemes have a great power of encouragement and assistance. Animation is a dynamic tool for expressing concepts which in the case of engineering can be a powerful way to easily explain complex ideas. In addition, a new symbology language (emoticons) is used to complement textual messages in the web. These formats have a great amount of visual content and its role is, far from supporting textual information, to be a central communication content.

To date, the availability of Visual resources supported by tablets, and mobile devices in general reinforces strongly the possibilities of developing Visual Literacy competences.

In addition, new generations grew with the use of digital resources and are most habituated to work with visual materials rather than only texts. Digital-based visual materials must play a central role in a today's student's training.

Engineering processes suffered a paradigm change by the implementation of computer systems. Apart of tools for 2D drafting and 3D modelling, engineers use computer systems for analysis via finite element modelling, as well as simulation of mechanisms created on computers. Most of the results of these analysis and studies are shown visually in three dimensional representations, which express physical behaviour for example using colour codes.

Nowadays, the master design information changed from the engineering drawings to 3D models. Ronald E. Barr showed in 2004 that in a concurrent engineering process all the design information is based on the 3D model sources. The way that engineers express and perceives depends highly on digital means.

Mixed reality (Virtual and Augmented Reality) offers new ways for visual communication. Virtual Reality enables the visualization of concepts in a more enhanced environment than graphic expression. It allows representing the interaction with products not yet made and allows an immersive impression. Augmented reality enhances the real world with elements created by computer graphics and leaves a clearer evaluation of a new design.

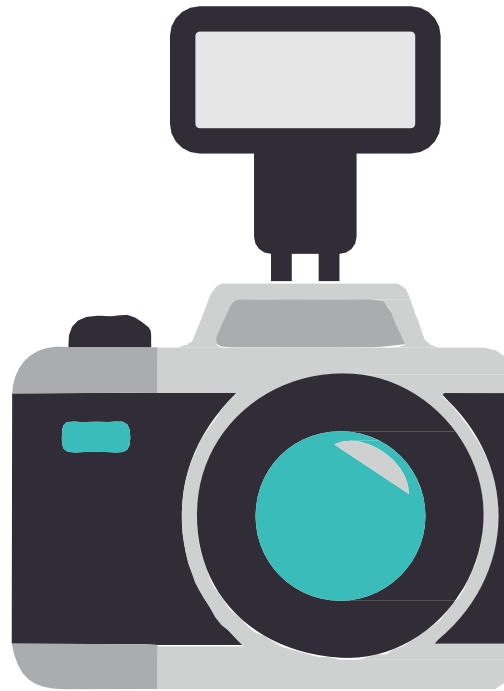


STEM EDUCATION



Visual Literacy in Engineering Education

From childhood to higher education, images, photographs, drawings and schematics play a significant role in our learning process. Far from being a support media for texts, students require to be well skilled to analyse, interpret and evaluate visual materials. Against the affirmation that these visual abilities are innate, one of the conclusions of the researchers is that Visual Literacy can be taught. Visual literacy is a skill that can be learned and improved like a language, by training on their pictorial and symbolic elements.



In addition, the learning process is benefited by the intervention of visual tools. By combining visual and verbal contents we can assimilate better complex concepts. Visuals allow to keep the attention better than just text.

Visual Literacy must be taken into account in engineering and VET educational programs. Professors Miller and Bertoline demanded that formal training of Visual Literacy should be required in engineering programs. They explained in 1991 the great importance of Visual Literacy for engineering education, remarking this requirement for an engineer to be a successful designer. The different types of visual information that an engineer processes are reflected in his academic stage. Students must understand, and create drawings, sketches, schemes and data representation in the same way that they will use and apply in his career.

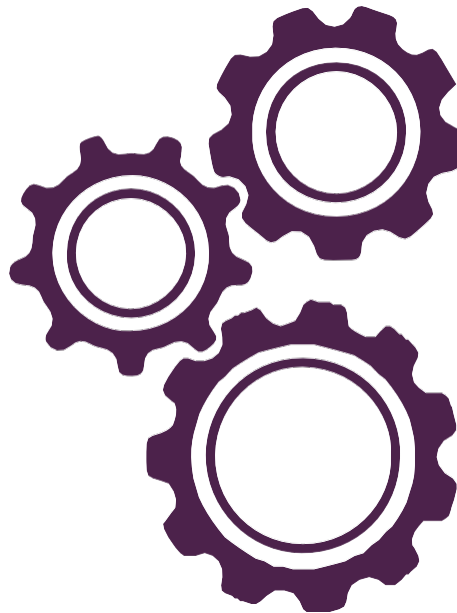
As Miller and Bertoline indicated, Engineering Graphics are the subjects where Visual Literacy was traditionally taught in engineering. Students learn how to interpret and create engineering drawings, which express technical concepts. Apart from that, an engineering student must also become a visual problem solver, able to process perceived information, which may be visual or verbal and generate ideas in his mind's eye. He also needs to acquire a high skill to quickly and clearly express these visual ideas.

There is a clear need to take into account the development of Visual skills in engineering curricula in the same way as analytical skills are. The key to have creative and innovative engineers depend on this.

The worrying question is that Visual Literacy is still scarcely present from engineering curricula. Since the only way to develop this is through engineering graphics, this subjects also suffered a decline and even disappeared from some engineering programs.

Miller & Bertoline demanded that engineering education is not aware of the importance of Visual Literacy, indicating the lack of emphasis or inclusion of subjects for its development. They also appealed the consequences derived on the lack of the basic visual literacy skills required for an engineer. The Association of College & Research Libraries (ACRL) mentioned the scarce preparation of students to handle images according to Visual literacy expectations.

The fact is that engineering students are habituated to handle visual information, but they are not expected to explore the great potential that brings them to be Visually Literate.

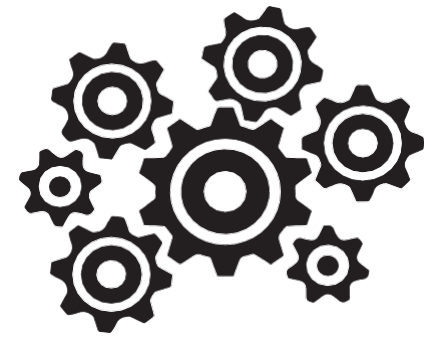
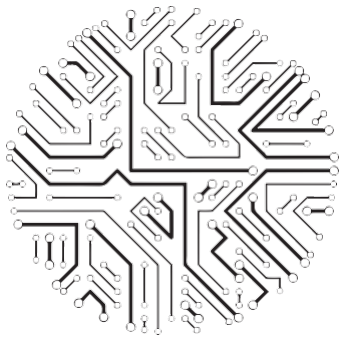
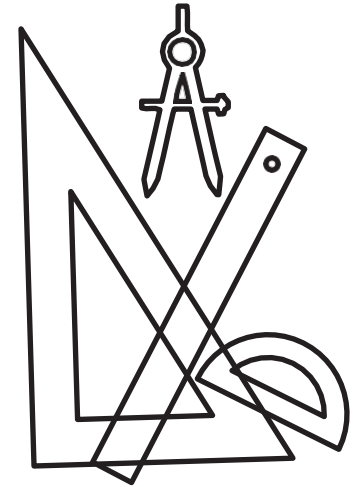


The VLEE project task force performed in 2020 a research to find how Visual Literacy was present in engineering education and VET, confirming the above mentioned situation shown by authors.

Our research identified several cases (two cases) of graphic subjects in Engineering which takes into account creativity. In the VET programs reviewed, we could not identify any similar approach.

Considering the Future of Engineering Education in order to make the required changes in the engineering curricula, one of great importance is to have Visual Literate engineers.

It is important to educate engineering students taking into account their visual literacy which is required for supporting the visual environments in which technology is highly involved.



EDUCATION



The VLEE project

VLEE project pursues to foster the Visual Literacy of engineers across its participating countries and further afield by introducing innovative Visual Literacy training into Higher Education as well as into Vocational Training.

This project was motivated for the need of developing Visual Literacy competences in the field of Engineering Education. Although there are other similar projects on Visual Literacy (CEFR-VL), it is focused on Arts Education.

With the objective to enhance Visual Literacy competences of engineers by proposing innovative pedagogical strategies, the VLEE project was set up in 2019.

VLEE project includes representatives from Poland, Spain, Denmark, Ireland and United Kingdom, covering the scope of Higher Education and VET organisations.



The work on the VLEE project has been supported by the European Union's Erasmus + programme between December 2019 to December 2021.

One of the goals of this project was the development of this competence Framework for Visual Literacy.



Development of the Competence Framework

Research

VLEE Competence Framework has been developed as one of the parts (Intellectual Outputs) of the VLEE project.

UPM led the development of Visual Literacy for Engineering Education Competence Framework. This was mainly a qualitative approach, in which empirical-practical studies were carried out. The members of the VLEE project pertaining to the UPM coordinated and worked since research to final design of the guide with the support of the project partners. Open discussions held in meetings and communications via email were conducted to agree several aspects of the framework.

Four stages for the development of VLEE competence framework were defined. These correspond to the Research, content Development, Testing and Final design of the framework guide.

The research methodology was developed by the UPM and presented to the project partners in the VLEE project first transnational meeting.

Proposed research consisted on a set of specific tasks aimed at covering the research objectives of defining the specific visual competencies for engineering, the definition of a competence model and rating scales.

The approach was initially to check reviewing materials according to a theoretical base which allowed to identify the specific characteristics of Visual Literacy in engineering. Secondly, to define the main elements of our competence model, by an analysis of similar frameworks.

This methodology was in part theoretical, based on descriptive work in the form of reviews and in-depth analysis of literature and relevant publications as well as practical tasks in order to fit competencies enlisted from Framework analysis to European Union Engineering Education reality.

Research methodology was reviewed and finally accepted in the first VLEE transnational meeting. The methodological approach taken was made up of six research tasks:

- Comprehensive review of academic, and grey literature as well as policy documents.
- Development of a Theoretical Basis for VLE Competence Framework.
- An inventory of existing competence frameworks most related to VLE.
- In-depth analysis of selected frameworks and VLE skills assessments.
- Interviews/Discussions between project partners.
- Academic, students and experts' surveys and consultations.

1) Literature review

UPM team members coordinated to carry out the research according to the agreed methodology. Research started with an extensive review of academic and grey literature. The key aims of this literature review was to:

- Study the role of Visual Literacy in Engineering.
- Clarify a definition of Visual Literacy
- Study the main features of Visual Literacy in engineering.
- Review the state of the question from the academic point of view.

Data collection and content analysis covered a wide range of materials such as journal and conference papers as well as book chapters. Relevant books related on Visual Literacy and Engineering Graphics were reviewed. As a result of this references compilation and following the initiative taken by ACRL, VLEE Research team created a free-access bibliography in Zotero Database for further consultations.

2) On line Research

Online research was conducted to follow literature review from the non-academic sources as well as to review policy and practice documents registered in websites. Wikis and blogs were also reviewed in order to identify insights about research questions. It was collected a set of Competence Frameworks related to Visual Literacy in Engineering and most related to our research goals (E.g. CEFR-VL and DIgComp).

3) Theoretical Basis of VLEE

A theoretical basis of specific characteristics of VLE was developed. Our goal was to clarify the definition of the Visual Literacy, the definition of competence as well as identify the main characteristics of Visual Literacy in Engineering. This work was performed from a review of literature, by selecting and analyzing academic works related to these topics. The results were then subject to discussions among VLEE project partners. This basis gave the guideline for mapping the VL skills specific to Engineering.

4) In-Depth literature analysis

The aim was to analyse in-depth selected academic works from literature review and compare collected VLE skill lists in order to identify commonalities, points of divergence and gaps. In addition to VLE skills list extracted from literature, new skills and abilities list were elaborated according to a thematic analysis of selected academic works. This analysis allowed to identify VLE skills and key competences. This analysis gave a previous list of specific characteristics as well key competence/skill areas of VLE.

5) Review of frameworks

A review/mapping of collected Competencies Frameworks was performed. For this selection of frameworks the following criteria was taken into account:

- Framework contents allow for an in-depth analysis for VLEE skills and competences identification.
- Applicable to Higher Education level.
- Theme of the competence Framework (Engineering, Visual Literacy and Digital Competencies).

Mapping of the frameworks was then performed using a mapping schema that is developed according to This Competence Framework Goal. This comparison of selected Frameworks clarified a structure of the competence model.

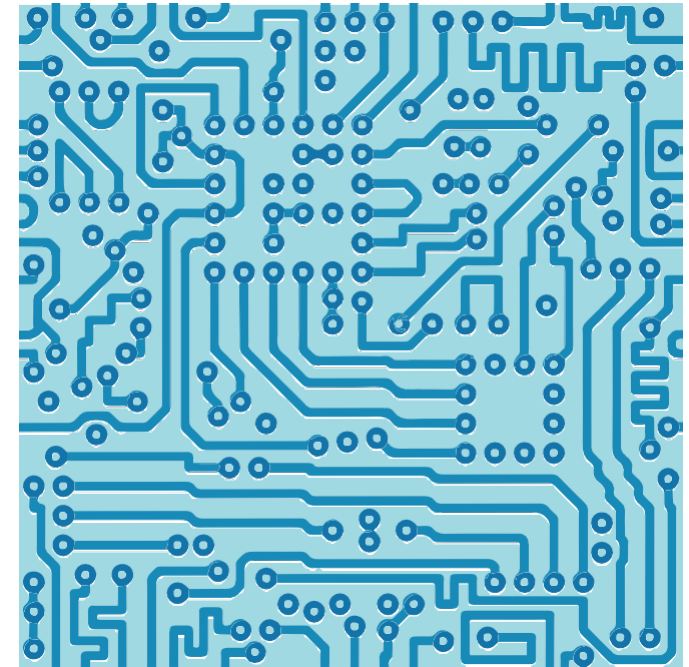
In-depth analysis of Framework inventory was conducted for commonalities, similarities of skills, competences and subcompetences, taking into account Visual Literacy for engineering theoretical basis. Outcomes were a competences list, the addition or deletion in case of any preidentified skill or competences from the in-depth literature analysis.

6) Surveys/interviews

The goal of this surveys was to clarify the state of visual literacy in engineering and vocational education by identifying the current teaching strategies addressed for this purpose.

A research on academic programs as well as for students and teachers was planned to identify the state of question as well to identify current VLE learning strategies. As attitude is part of a competence, it is also expected to know student's confidence about relevant VLE skills.

Skills and abilities development from existing engineering programs were assessed to identify VLE competence areas and subcompetences in curricula as well of identifying methods and learning strategies.



Surveys/interviews to engineering students were intended to clarify their attitudes/skills in identified VLE competences from in depth analysis and then determine means for learning. For example: spatial abilities as well as sketching skills for an engineering design expression.

Surveys were administered using Google Forms to engineering faculties and VET institutions from Poland, UK, Ireland, Denmark and Spain. Participants on this study were contacted through email. Surveys results gave important confirmations about the confidences of students on Visual Literacy, as well as current pedagogical approaches to enhance Visual Literacy in engineering education.

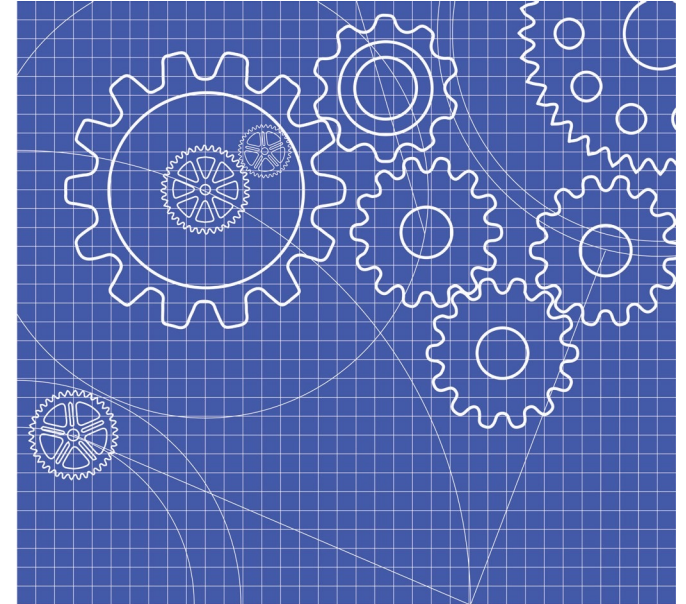
Development of the Competence Framework

Content Development

Theoretical and empirical research results gave the required information to develop VLEE Framework, as well as other contents required for the other intellectual outputs to be developed in the VLEE project (education toolkit and an on-line application):

- List of VLE key competence areas
- VLE competences
- Competence Scaling
- Pedagogic strategies to develop these competencies

With the information resulting from research, UPM started the development of the the framework guide. A graphic definition of the Competence Model was created in order to allow the understanding of its structure and elements. Narrative sections and visual elements for this guide were elaborated to ease its utilization by the target groups which covered EHEA countries as well as all engineering areas.



Development of the Competence Framework

Testing

Final design and production



Based on the feedback received by the members of the UPM presented an updated and more elaborated version (full draft) of the guide.

This first document was presented and discussed internally at the 2nd Transnational meeting of VLEE project held online.

The same materials were sent also to the experts for their validation. Each partner shared it with three representatives of VET and HE Institutions or Engineering stakeholders and policy makers, asking for their qualitative feedback using a predefined format.

Once feedback results were received UPM carried out the production of this guide following the criteria of ease of use and presenting a pleasant graphic design.

Each partner contributed to the translation of the texts into their own language, eventually publishing the guide in Polish, Spanish, English and Danish.



VLE

Competence model

The VLEE is intended for Higher educational organisations and VET schools to self-reflect on their progress in integrating and effectively using Visual materials. It is expected that Visual Learning and Visual thinking shall be widely regarded by educational organisations as an important element for innovative education. From this perspective, the progressive integration and effective use of Visual skills and abilities can have the character of increasing the quality of technological education.

*“The European Qualifications Framework (EFQ) defines Competence as ‘the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy’
(Recommendation 2008/C 111/01).”*

The competence framework here presented can be used complete, or partially, depending on specific needs and the engineering domain. It is intended to include its contents in the engineering subjects’ educational programs as Visual literacy competences are implemented.

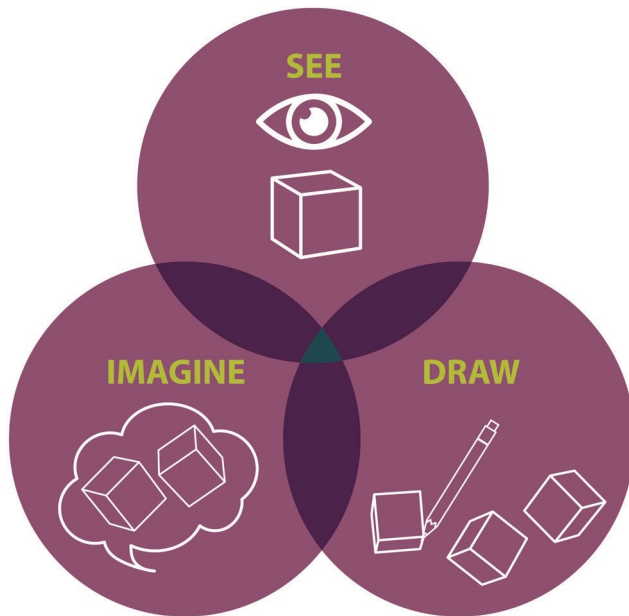
Each of the competencies and their scales can be treated individually or in specific sets, according to specific teaching strategies. Depending on a specific task, it is possible that some competences are required and other from the model are not applicable. In the other hand, the development of competences may also vary across technical disciplines, depending on how visual materials are used in each engineering domain (e.g. mechanical engineering vs. electronic engineering).



VLE

Competence model

Description of the model

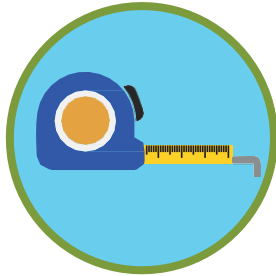


VLEE is structured in six different areas in which engineer's Visual Competences are expressed. Each of these elements reflects a different aspect of the engineering processes of integrating and effectively using Visual resources and materials. Figure 1 (p. 29) provides a graphic representation of VLEE with its areas and competences:

VLEE areas focuses on the general engineering processes for product development for across a range of all engineering domains. In addition, competence areas are interrelated to the Visual Thinking processes as it was defined by Robert McKim: (See-Imagine-Draw). The stage of the Visual Thinking process: "See" is related with the competence area 1 (Use) and competence area 2 (Interpretation). Competences into this key competence area covers the skills and abilities for perceiving, interpreting and reading visual messages. For the part of the Visual Thinking process: "Imagine", are related the competence area 3 (Analysis) and area 4 (Solving). Competences into these competence areas cover the skills and abilities for visual reasoning, visualization and creative ideation. For the part of the Visual Thinking process "Draw", are related with the competence areas 5 (Creation) and Competence area 6 (Communication) which covers the skills and abilities for expressing visually. The core of the VLEE framework is defined in following sections. Together these areas explain Visual Literacy competences that engineers require to improve the development of their work in a creative and innovative manner.

Six competence areas

Use



Use of images/objects for engineering tasks.

Interpretation



Perceive and understand visual information. Interpret the technical meaning of visual resources.

Analysis



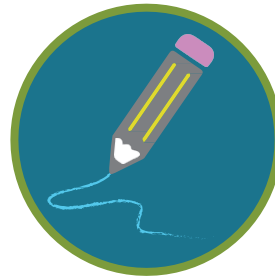
Analysis of visual information. Is related to the competence area of interpretation.

Solving



Find problem solutions with the help of visual means. Use visual thinking to conceptualize solutions to problems.

Creation



Generation of meaningful visual resources. Production of images and objects for ideas expression.

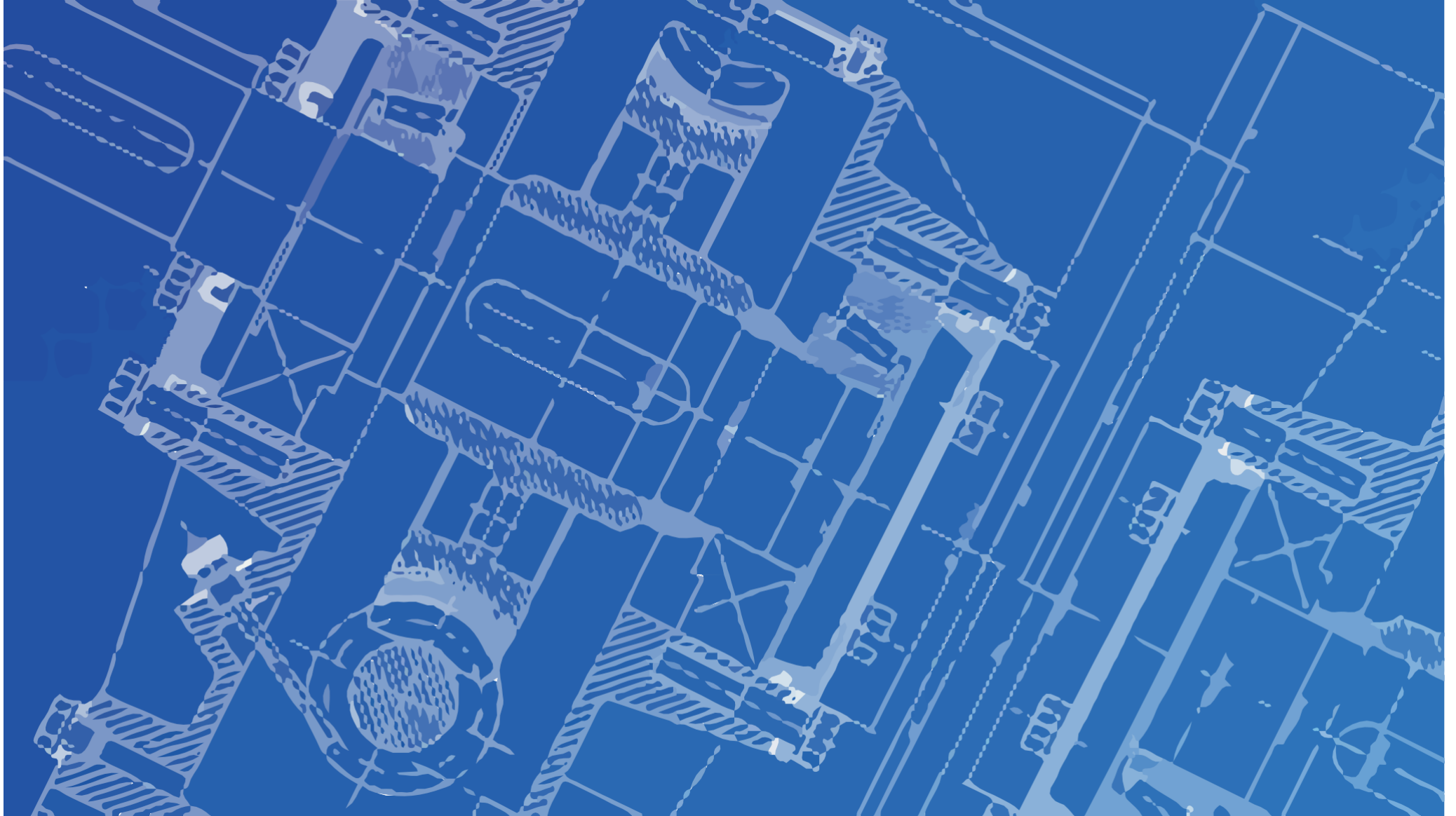
Communication



Use visual resources to share or exchange information



Figure 1 Graphic summary of the VLEE competence framework



VLE

Competence model

Proficiency Levels

In order to evaluate the degree of progress in the development of visual competences, a gradation in levels has been established. VLEE thus provides a measuring resource for evaluating student's progress. The levels correspond to the specific scope of a target in relation to an ability or skill. In some cases, activities related to competence at an specific level are also described.

Three level scale was agreed for the proficiency progression of competences. As in other cases, a wider range of levels is presented, we adopt the similar approach as the CEFR-VL (the Common European Framework of reference for Visual Literacy) of "Basic", "Intermediate" and "Competent". In our case: "Basic", "Intermediate" and "Proficient".

Bloom's revised taxonomy was taken into account in the competence levels definition, as this taxonomy is in line to the cognitive phases of any learning development: "Remembering", "Understanding", "Applying" "Analysing", "Evaluating" and "Creating". Therefore, Bloom's first stages "remembering" and "understanding" corresponds to Basic proficiency level. The Intermediate level with the stages "Applying" and "Analysing", and the Proficient level to "Evaluating and creating".

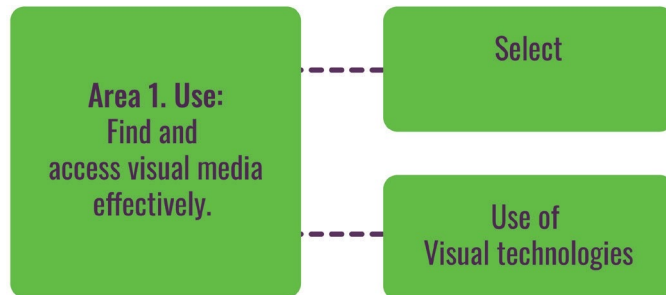
At the basic level, engineers acquire new information and develop basic Visual and Graphic practices. At the Intermediate level, engineers apply, further expand and reflect on their graphic and visual practices. Finally, at the proficient level, engineers transfers their knowledge, critique existing practice and develop new ones.

This agreed competence levels can be described with the following characteristics:

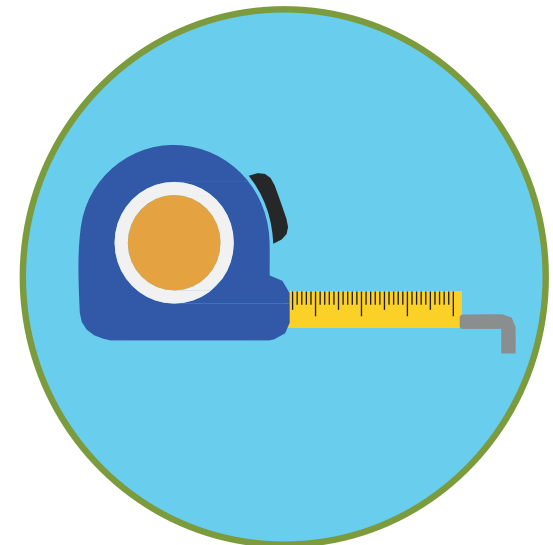
- **Basic:** This level shows an elementary approximation of the competence. It allows to understand simple tasks and have the notion to use the competence to achieve a goal.
- **Intermediate:** It shows an observable advance in the achievement of the competence. Able to explain a task according to multiple aspects.
- **Proficient:** This level indicates a clear achievement of the competence. Apply appropriate competence to the resolution of a complex task or challenge. Create solutions to such complex problems or situations.



Competence progression here defined is cumulative, so Intermediate and Proficient levels comprise Basic and Intermediate levels respectively. Adequate competences learning outcomes can be applied according to specific educational needs, and Visual Literacy learning may not necessarily follow a sequential progression from competence Area 1 to competence Area 6.



The effective use of images, graphics or objects for engineering tasks. Is expressed in the ability to use Visual Media in an effective way, not only enhancing individual capabilities, but also for their professional interactions with colleagues and other interested parties, for their individual professional development and for the collective good and continuous innovation in the organisation and the engineering profession. In doing so, existing images, graphics and products become means to help reaching specific goals according to the engineering process. This competence area therefore describes the act of working with visuals as resources.





Select

Identify effectively the adequate visual resource for a concrete purpose within the engineering process.

To identify, evaluate and select digital resources to support and enhance learning and teaching. To take into account the specific learning goal, environment, pedagogical approach, and learner group when selecting digital resources and planning their use. To articulate information needs, to search for data, information and content in Visual environments, to access them and to navigate between them. To create and update personal searching strategies. To organise, process, analyse and interpret visual information. Identify adequate visual tools and technologies for each technical task. To formulate appropriate search strategies to identify visual resources for each engineering task.

Examples:

- Find visual information and resources in digital environments.
- Use Visual digital tools to identify and solve conceptual problems or issues through technological means.
- Access needed images and visual media efficiently and effectively.
- Identify adequate visual tools and visual technologies for each task.
- Find visual information and resources in digital environments
- Understand the need for sketching in relation to CAD.
- Use the appropriate graphic tool for specific engineering task.
- Identify the available graphic tools for engineering tasks.



Select

Proficiency Levels:

Level	Progression Description
Basic	Recognise simple visual tools to solve engineering tasks needs. Identify available graphic techniques for design tasks. Identify simple visual resources and technologies that can be used to create knowledge and to innovate processes and products.
Intermediate	Select well-defined and routine visual tools and possible technological responses to solve those needs. Select graphic techniques required for the engineering design task. Can select technical expression strategies from among a number of options and use them appropriately
Competent	Identify the appropriate graphic technique. Identify the need of using digital visual resources or freehand graphic tools. Consult a range of available visual techniques and choose those which best fit to the task needs.



Use of Visual technologies

Use the required graphic tools for engineering

practice. Able to use every graphic technique. Use visual media effectively.

Skills, abilities and knowledge related:

- Skills of different digital graphic tools for engineering tasks.
- Generation of 3D models.
- 2D CAD.
- Drafting.
- Freehand sketching.
- Virtual prototyping.

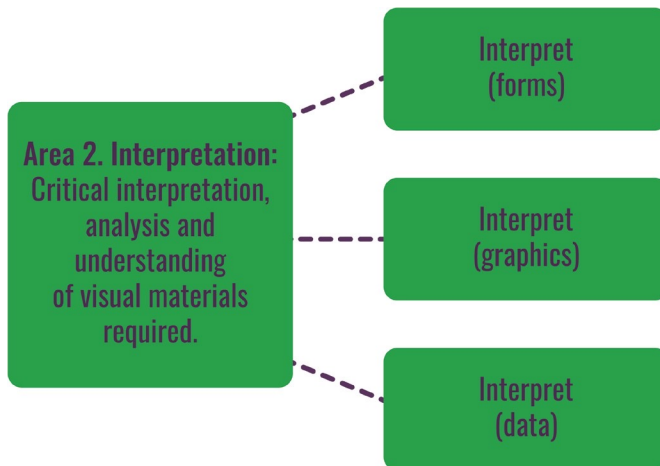
Examples:

- Use of a digital learning platform to improve spatial abilities.
- Apply freehand sketches for developing brainstorming ideation.
- Generate a 3D model by compatible software for the project requirements.
- Using Visual digital tools (e.g., Tablets) to identify and solve conceptual problems or issues.

Proficiency Levels:

Level	Progression Description
Basic	Use simple visual technologies to apply for developing technical processes and products. Making little use of visual technologies. Rarely use available visual technologies to update self knowledge and skills.
Intermediate	Apply different visual tools and technologies for developing technical processes and products. Exploring the available visual technologies to apply for engineering tasks.
Proficient	Use the most appropriate visual tool to apply for developing technical processes and products. Use every available graphic techniques appropriately.

Interpretation



Perceive and understand visual information. Interpret the technical meaning of visual resources. Understanding of the topic/subject through ideation and graphic expression. Interpretation involves perceiving as the perception process from external sources and then its recognition after comparing to mental representations.

Interpretation requires prior technical knowledge, knowledge of the function of the part/set and significance of standardized symbols, dimensions and forms of representations. Also to identify the design intent, for the purpose of a visual engineering representation to be interpreted.





Interpret (forms)

Interpretation of an element/assembly using engineering means and developing a specific understanding of the element through creation.

Understand the meaning of an element/ assembly in terms of technological purposes.

Skills, abilities and knowledge related:

- Visual perception/discrimination/recognition .
- Understanding of an object through creation.
- Visual Association.

Examples:

- Translate the effect of an image into ideas and concepts.
- Perceive the functionality of a part/assembly.

Proficiency Levels:

Level	Progression Description
Basic	Can make a suggestion on the topic and the function of image/ object. Can separate the basic elements and the functions of a simple mechanical assembly or a mechanical object. Able to interpret simple orthographic representations.
Intermediate	Can identify the basic elements and the functions of a mechanical assembly or a mechanical object. Interpret Design intent as the principal functions of a part and a simple assembly.
Proficient	Can apply various methods to interpret images/objects. Can identify the elements and the functions of a complex mechanical assembly/mechanical object.



Interpret (graphics)

Interpretation of an engineering graphic representation. Process a graphic representation to find its meaning. Perceive the design intent of graphic representations.

Skills, abilities and knowledge related:

- Understand 2D graphic representation of three dimensional models
- Skills to facilitate critical interpretation, analysis and understanding of graphic, image-based and video resources
- “Read” the drawings with accuracy.
- “Read” engineering symbols in order to derive their meaning. Knowledge of engineering symbols as well as standardized elements of the Visual language of engineering.
- A high level of visualization ability for reading drawings with accuracy, as Miller & Bertoline (1991) recommends.

Examples:

- Clearly interpret a 3D wireframe model.
- Interpret a 3-view orthographic representation.
- Identify the design intent of an engineering drawing.

- Identify the design intent of a 3D CAD model.
- Generate an image of an object/element from its partial representation.
- Examine engineering drawing elements (sections, broken out sections, auxiliary views)
- Perceive Design intent in engineering drawings.

Proficiency Levels:

Level	Progression Description
Basic	Identifies the symbols, pictorial elements and drawing standards for defining an engineering drawing and those required for reading it. Can identify the Design intent on engineering drawings. Can identify and functionality of parts.
Intermediate	Selects the symbols, pictorial elements and drawing standards for reading an engineering drawing. Can describe perceived Design intent on engineering drawings and function of simple machines.
Proficient	Uses visualization to interpret drawings, sketches to understand the meaning. He has a full knowledge of the symbols, pictorial elements and drawing standards for reading an engineering drawing. Can check a drawing with accuracy. Can describe perceived Design intent on engineering drawings and function of complex machines represented.



Interpret (data)

Examples:

- Interpreting diagrams, tables, equations, graphs.
- Understanding Information Graphics Graphs and charts present facts and figures in concise visual ways, while diagrams offer a clear picture of objects and other structures, highlighting the parts of each and their relationship.
- Interpret the results of a 3D FEM/CEFD model.
- Understand the results of a simulation program.
- Understand the meaning of three-dimensional data representations.
- Read three-dimensional data representations shown in FEM and CFD models.

Interpretation of all available data representations expressed by visual means creating and interpreting diagrams, tables, equations, graphs, as well as 3D FEM/CFD models. Interpret the meaning of data representations

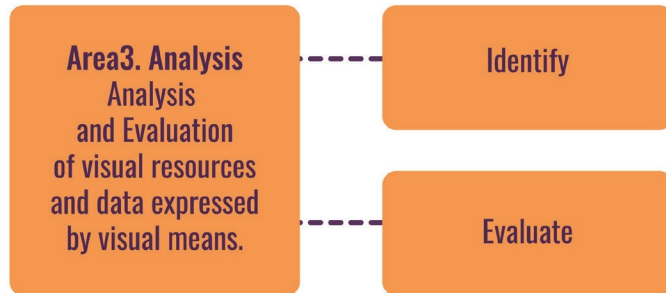
Skills, abilities and knowledge related:

- Knowing how to “read” different types of graphics to understand and evaluate the information that is represented.
- Reading Diagrams when looking at diagrams, paying special attention to all labels, colours, shapes, textures, symbols, scales, arrows, and numbers.

Proficiency Levels:

Level	Progression Description
Basic	Being able to interpret simple data representations.
Intermediate	Being able to interpret most common types of data representations
Proficient	Interpret all types of data representations. Being able to explain to others.

Analysis



Analysis of visual information. As a receptive competence, is closely related to the competence area of interpretation. It means a further step following the perception/interpretation of a part/assembly.

Analysis is a set of methodological competences, particularly with regard to methods in engineering education.





Identify

Identify visually characteristics of engineering designs. Critical analysis of visual information.

Skills, abilities and knowledge related:

- Visual Association.
- Visualization.
- Knowledge of technical Visual Language (symbology, conventions, pictorial representations).

Examples:

- Functional decomposition of an assembly/ design.
- Identify characteristics of engineering designs.
- Identify european-american dihedral projection conventions.
- Identify the elements of a standardised engineering drawing (dihedral convention, line types, Bill of materials, symbols, use of auxiliary views).

Proficiency Levels:

Level	Progression Description
Basic	Can name obvious elements of engineering designs. Can identify the main functionality of an observed part/assembly. interpret simple data representations.
Intermediate	Able to separate a part taking into account their specific function of separated elements. Can select the elements of less familiar elements of engineering designs and describe their characteristics. Identify the main components of and engineering drawing.
Proficient	Can present significant visual features of elements of complex, unfamiliar engineering designs. Have a clear identification of the main elements of an assembly according to their functionality.



Evaluate

Evaluation of images and Visual information. Evaluating Visual data, information and Visual digital content. Critical analysis of forms

Skills related:

- Visualization.
- Spatial abilities.

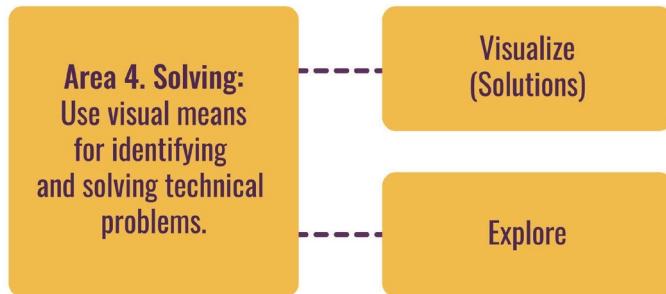
Examples:

- Evaluation of the results of a FEM model.
- Critical evaluation the credibility and reliability of visual information and its sources.
- Study how to simplify a mechanical element to reduce its elements.
- Evaluate the constructive tree of a CAD assembly in order to optimize its structure.
- Mental rotation, combining a three-dimensional figure to examine its elements to see if it is manufacturable.

Proficiency Levels:

Level	Progression Description
Basic	Is aware of the basic elements of an engineering drawing are required to define a part.
Intermediate	Able for evaluation of basic visual tools. Can evaluate if an engineering drawing includes all the required elements to define completely the part/assembly.
Proficient	Evaluate all types of visual information and communicate to others. Is able to examine critically an engineering drawing as well as to suggest improvements.

Solving



Find problem solutions with the help of visual means. Use visual thinking to conceptualize solutions to problems. Ideation using visual means. Visualization, Spatial abilities, Visual Association and Visual reasoning are implied in this competence area.





Visualize (Solutions)

Generate an image of the problem solution in the mind.

Manipulate mental images (combine, modify) to solve problems. Use various forms of visual representation to solve technical problems. Use visual techniques to solve a specific problem.

Skills, abilities and knowledge related:

- Visualization.
- Spatial abilities.
- Visual Association.
- Visual reasoning.

Examples:

- Represent in mind the assembly of a part with a new element.
- Visualize in 3D mental objects that represents technical problem solutions.

Proficiency Levels:

Level	Progression Description
Basic	Making little use of Visual Thinking Strategies fostering Visual problem solving Rarely consider how to find a problem solution by visualization. Visualize a simple solution to solving a problem.
Intermediate	Encouraged to use visual thinking to solve problems. Visualize several solutions to a simple problem. Developing visualization activities. Able to manipulate mental images (combine, modify) for problem solving
Proficient	Comprehensively and actively use of Visualization for problem solving. Creatively application of Visualization visualizes various solutions to solving a complex problem. Able to simulate mentally the function of a mechanism.



Explore

Using graphic representations to solve problems.

Develop an idea or concept by visual perception and the mental processing derived by exploring and reflecting, that involves searching and exploring of alternatives and idea variants. Drawings and 3D models often play a Key Role in this process, mainly freehand sketches. So, it is related to Interpretation and Visualization. Explore means a cyclical process involving visual perception, interpretation, envision and expression. Is therefore related to these competences.

Skills & knowledge related:

- Visual Thinking.
- Spatial abilities.
- Visual Association.
- Visual reasoning.
- Freehand sketching.

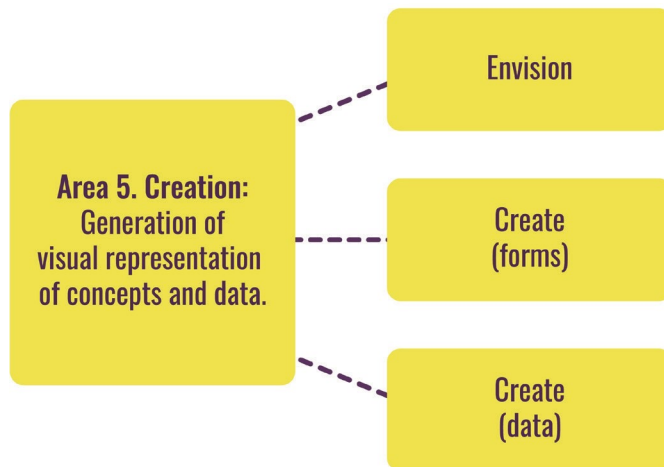
Examples:

- Explore design solutions by analysing sketches, drawings or 3D models.
- Quickly freehand sketch an idea created in the mind's eye.
- Sketch 3D images onto 2D media by visualizing. (Sketching and logical process skills which use drawing and design to facilitate cognitive processes, design thinking and creativity in problem solving).

Proficiency Levels:

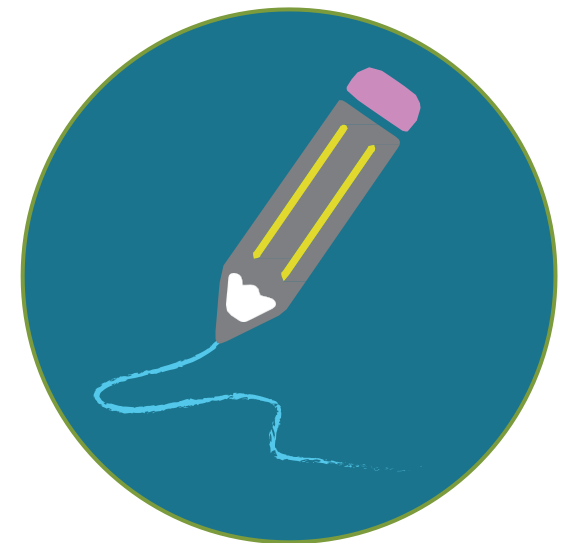
Level	Progression Description
Basic	Recognise the value of the interpretation of an observed drawing to find a problem solution. Can develop own technical ideas in a basic way when given structured requirements.
Intermediate	Can design sensible steps with regard to an idea using specific graphic expression means and made adequate decisions. Can take in and implement changes during the exploration process. Express ideas from the interpretation of a sketch drawn by oneself.
Proficient	Develop several ideas and problem solutions by envision images from self drawn sketches and express these solutions by free-hand drawing.

Creation



Generation of meaningful visual resources.

The production of images and objects for expression of ideas. To create means to process and give form to the concept intended to be expressed using selected methods and resources. It can be related to creative process depending on the intention and or function of creating (e.g., to express graphically, to present, to study or to visualize). Express creatively through digital media and technologies. To generate knowledge with the support of digital visual tools. Create is closely linked to methodological competences for handling different visual resources applied during the creative process. It also depends on technical rules (conventions, regulations, standards) as well as knowledge related to using media, resources and tools.





Envision

Generate images in mind from perception and from visual images earlier visual impressions. It is related to Visualize (solve) but envision cover mental imaging in general and not for problem solving. It is anyway linked to interpret (forms).

Skills, abilities knowledge related

- Visualization.
- Visual Association.
- Visual perception.

Examples:

- Define a technical problem by envisioning the requirements and constraints.
- Use perception to visually represent internal images from external stimuli.
- Create mental images when using computer tools for modelling.

Proficiency Levels:

Level	Progression Description
Basic	Making little use of Visual Thinking Strategies for envisioning Rarely consider how to generate a specific image by visualization.
Intermediate	Encouraged to use visual thinking to define problems. Visualize definition of a simple problem. Developing visualization activities Able to manipulate mental images (combine, modify) for creating a new one
Proficient	Comprehensively and actively use of visualization for internal expression of ideas. Combine visual imagery and perceived images to generate new ones. Simulate situations or scenes mentally.



Create (forms)

The intentional production of components/assemblies. It is based on a specific intention or an undetermined idea. To create means to process and give form to the topic of what is to be created using selected methods and resources. In the creative process it is followed by the competence Explore and it precedes to Express (present). To create means primarily to purposely develop the visual form of engineering designs. It may be linked to creativity to a greater or lesser extent depending on the intention and or function of creating (e.g. express, present, explore).

Skills related

- Visualization.
- 3D modelling.
- Prototyping.
- Crafting.

Competences related

- Express (realise).
- Explore.

Examples:

- Creating physical mock-ups.
- Creating rapid prototypes.
- Generating virtual mock-ups for simulation.
- Creating prototypes.
- Use of digital manufacturing.

Proficiency Levels:

Level	Progression Description
Basic	Identify ways to create forms in simple materials and techniques. Rarely consider how to generate a specific form
Intermediate	Select ways to create forms in different materials and techniques. Developing visualization activities Apply for generating a physical expression of an idea
Proficient	Being able to define forms in detail. Use comprehensively and actively of modelling tools and techniques for idea materialisation.



Create (data)

Create visual media that represents data.

Skills related:

- Digital tools for data graphics from collected data.

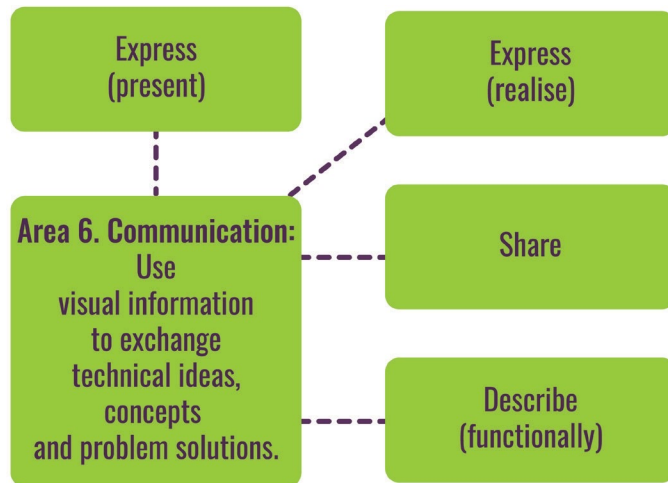
Examples:

- Creation of diagrams, tables, equations, graphs.
- Using three-dimensional for complex data representation.

Proficiency Levels:

Level	Progression Description
Basic	Identify ways to create and edit simple data representation in the usual formats.
Intermediate	Select more specific formats to create and edit data representation.
Proficient	Apply the appropriate format and scale to efficiently represent data in graphic format.

Communication



Use visual resources to share or exchange technical information. Communication in engineering involves knowledge of all areas of the competence model: technical, educational and ideation, as well as those related to the audience and its environment.

Communicating by visual means requires understanding how to convey information visually and verbally, taking into account the specific audience. Communication also means knowledge of visual grammar and syntax as well as knowledge of visual vocabulary. This means having knowledge of the basic components of visual technical language and visual standards, signs and symbols.





Share

Share ideas/concepts, narratives, or arguments with visual media.

Exchange visual technical information. Make visual information and visual forms perceivable for others in a specific format.

Skills related:

- Identify the adequate audience and environment.

Competences related:

- Select.
- Express.

Examples:

- Sharing through digital visual technologies.
- Digital format public presentation (e.g., powerpoint).
- Prepare group work with classmates using graphics.
- Draw a sketch in a meeting so show an idea.

Proficiency Levels:

Level	Progression Description
Basic	Can arrange one or more visual resources under consideration of the given context (medium, place and time of the presentation) in such a way that personal topics become clear. Can arrange one or more visual objects in such a way that others take notice of them.
Intermediate	Can select visual materials under consideration of their suitability and present them using basic creative methods while taking into account simple relationships between form and content with regard to the communicative intention. Can arrange images/objects in such a way that they capture the attention of the target audience
Proficient	Can consider the interaction between content, media, codes, forms of presentation and communicative goals when creating a presentation. Can show a larger number of visual materials in more complex context in such a way that the viewer understands the intention. Adapt the most appropriate communication strategies in digital environments to an audience.



Describe (functionality)

Describing perceived Design intent on engineering drawings and function of machines and engineering elements. To describe something technically is to express and register it appropriately. Identify the prominent characteristics of an engineering design.

Skills, abilities and knowledge related:

- Knowledge of drawing standards, including symbology and drawing conventions
- Visual association
- Graphic expression

Examples:

- Drafting of a complex assembly
- Sketch of a mechanical design

Proficiency Levels:

Level	Progression Description
Basic	Can copy individual aspects of familiar subjects to be considered is important using basic technical drawing methods. Can represent obvious elements of engineering designs using common visual language.
Intermediate	Can select visual materials under consideration of their suitability and present them using basic creative methods while taking into account simple relationships between form and content with regard to the communicative intention. Can arrange images/objects in such a way that they capture the attention of the target audience.
Proficient	Can record subjects or circumstances technically in a suitable medium in such a way that the results of these descriptions can be used to aid memory. Can select the elements of less familiar elements of engineering designs that are important for analysis and describe their characteristics using basic elements of technical visual language.



Express (Realize)

Implement, execute or put into service an idea of an engineering design. It means to implement an idea for an external representation. It is connected to the competence Explore, when it is applied in a self-creative process.

Skills related

- Knowledge of visual language for expressing concepts & ideas
- Sketching skills
- 3D modelling
- Visualization

Examples:

- Express an engineering idea in the form of a, sketch, a detailed drawing or a 3D model.

Competences related

- Create forms

Proficiency Levels:

Level	Progression Description
Basic	Can apply basic knowledge of graphic techniques when implementing ideas. Can Make a reasonable sketch of an object.
Intermediate	Can apply knowledge of the basic repertoire of graphic techniques and use them independently. Sketch an isometric view of an object.
Proficient	Can apply comprehensive knowledge of how to handle graphic techniques independently, confidently in a targeted manner. Render a sketch to make it look real.



Express (Present)

Communicate the final creation of a component/assembly, taking into account that is perceivable to others. So, design intent expression is a main goal for this competence. Express the Design intent on engineering drawings and function of machines.

Skills, abilities and knowledge related:

- Express visualization by graphic methods (e.g. drawings).
- Knowledge of Visual language, including symbols.
- Create assembly drawings.
- Spatial abilities.

Competences related:

- Select.
- Share.
- Envision.

Examples:

- Creating orthographic views of imaged designs.
- Generating Concept sketch.
- 3D modelling.
- Drafting.
- Study the different views required to describe an object, including the need to section it.
- Express a mental 3D object in orthographic views.

Proficiency Levels:

Level	Progression Description
Basic	Select the availability to use graphic expression means such as orthographic projection to describe form. Select the availability of some special view's sections, detail, broken out sections and auxiliary views. Rarely consider how to foster graphic expression through digital resources.
Intermediate	Use orthographic projection to describe form. Apply in case Special views sections, detail, broken out sections and auxiliary views critically reflect on the suitability in applying graphic tools and adapt accordingly to task needs. Strategically using a range of graphic tools for visual expression. Apply required standards for the appropriate technical representation.
Proficient	Define shapes in detail in engineering drawings, using sections, details, broken out sections and auxiliary views. Encourage others to apply innovative visual tools for graphic expression Using innovative graphic resources for visual expression.



Pedagogical Strategies

As Miller & Bertoline explained, Visual Literacy in engineering is commonly developed in the educational environment through engineering graphics subjects, by teaching technical drawing and in cases showing how to solve technical problems using graphics.

Research on engineering education present approaches to enhance Visual Literacy in students. The empirical works by Pu Siun Kai from Singapore University proposed a three-level course. First level introduces students in Foundation for visual perception and develops Skills of observation. Second Level inculcates in the students the skills of interpretation and analysing visual messages. Third Level is about how to create visual messages.

According to our approach of enhancing Visual Literacy by its competences, teaching efforts must be focused on the skills and abilities which most contribute to its development. First of all is Visualization and, more precisely for engineering, spatial visualization. Graphic skills are also usually common to VLE competences.

Several innovative teaching strategies with successful results are an adequate approach for developing Visual Literacy competences.

The so-called Visual Thinking tools (such as Visual Maps, sketchnoting or infodoodling) are creativity boosters and eases the interpretation of information via graphic representations.

Another important resource is mind mapping. Their use in education is to date widely applied, being an interesting tool for engineering problem definition.

Dana Statton Thompson, from Murray State University, studied in 2018 the use of infographics for increasing Visual Literacy. Infographics combines visuals and data having an important approach for developing communication skills for engineers.

Sketching practice covers communication, creation and solving competences. Both technical sketching as well as freehand drawing must be taken into account for engineer's Visual Literacy capabilities.

Along with drawing, computer graphics are a must for Visual expression and engineering solutions evaluation. A modern engineer must be well skilled in 3D modelling and for interpreting forms and volumes.

Journaling is another interesting initiative for enhancing Visual Literacy. Terry Loerts, from the Redeemer University College, evaluated the use of academic visual journals offering with interesting results on their improvement on creative thinking as well as expanded communication ways.

Current innovation of teaching and learning joint with the Digital resources offers interesting ways to develop Visual Literacy skills. Influence of TIC in learning is enormous. They increase engagement, allows flexibility, and are affordable.

Video-based learning is one of the best examples of improved technology in digital learning. From schools to coaching institutes and businesses, video-based teaching today is used almost everywhere to make learning more effective and engaging.

Video channels and video tutorials help explain complicated technologies and easily present the basics of engineering. Video tutorials are a great advantage for sharing theoretical concepts as well as "how to do it" in the fields of engineering. Apart from that, Kylie Burrett suggests in her blog the use of short instructional videos, indicating the case of the YouTube channel to help students develop visualization skills for design.

Video-based lectures are a good approach for enhancing distance learning by visualization of information rather than text.

Online learning offers a plenty of advantages for education. It enables direct access to instructive resources. Digital Tools also offer the possibility of Self-learning by using Visual Materials, therefore the competence development of Visual Literacy.

Distance learning suffered a quantum leap with the advent of internet. Nowadays, online courses are widely implemented in all educational levels. Digital communications give images a higher importance in information transmission and then in the pedagogical contents. MOOCs offer an interesting approach to develop Visual Literacy in distance, self-managed engineering education



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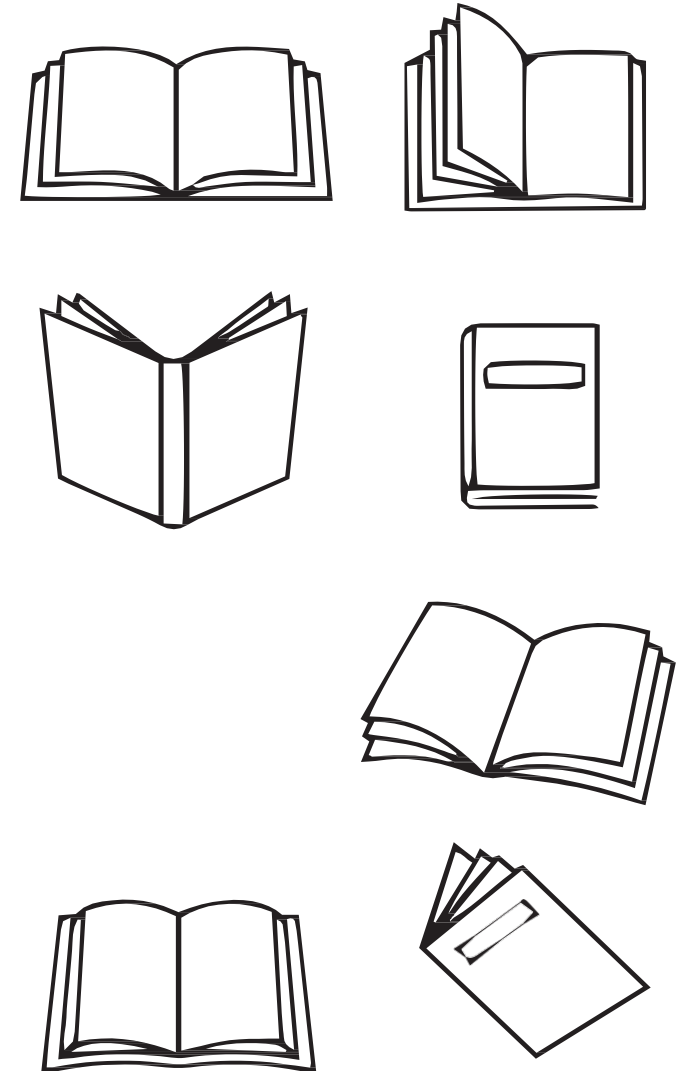
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Erasmus+