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# Art Education to Enhance Design Thinking for Underground Spaces

Yeraltı Boşluk Tasarımı Fikirlerinin Geliştirilmesinde Sanat Eğitimi

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**Abstract**

Humans need numerous raw materials to compensate for their covering, protection, and energy requirements. Anything obtained from the earth is either mined or grown. Considering excavation and mining operations for different purposes leads people to different design parameters. Living in the underground for civil purposes has its conditions to think about. Caves, abandoned mines, and new purposely opened underground excavations could be used for civil engineering purposes. Rock masses around underground openings opened for any purpose have rock-based structural features besides those originating from excavation operations. Therefore, engineers and designers working on underground space design projects should be ready to deal with them by enhancing their design ability, including their creative thinking. Concentrating on creative arts has usually been mentioned first to improve the original thinking capacity of designers. Uncertain conditions in engineering facts have forced designers to formulate their own solutions by accepting certain risks. Designing futuristic living spaces in/on rock masses needs creative thinking of workers, engineers, scientists, architects, artists, designers, etc. Moreover, skills and knowledge obtained from excavating and using historical underground cities, caves, tunnels, and underground mines for several purposes are also available for evaluation by creative designers. Combining those experiences with rock and soil engineering knowledge improves engineering designs' efficiency. Art and its education play an essential role in enhancing designers' imaginations and thinking capacities. Art's positive impacts on engineering creativity are discussed here to point out the importance of art and art education.

***Keywords:*** *Art Education, Creativity in Engineering, Enhancing Creativity, Creative Engineering, Art and Creativity*

**Öz**

İnsanların çevresel etkilerden korunma ihtiyaçlarını karşılamak için birçok hammaddeye ihtiyaç duyulmaktadır. Bu amaçla insanların dünyadan kazanımları, yetiştirdikleri ürünler ve yerkabuğundan kazarak, madencilik yaparak elde ettikleridir. Farklı amaçlar için yerkabuğunda madencilik veya yerleşim amaçlı kazı yapılması düşünüldüğünde, birbirinden çok farklı tasarım parametreleriyle karşılaşılır. Yeraltındaki boşluklarda yaşama amacı ön plandaysa, bu konunun üzerinde düşünülmesi gereken kendisine özgü şartları olacaktır. Mağaralar, terkedilmiş yeraltı maden ocakları ve sivil kullanım amacıyla açılan özel yeraltı boşlukları inşaat mühendisliği kapsamında sivil kullanım için değerlendirilebilir. Kayaçlar, kaya kütleleri içinde farklı amaçlar için kazılarak açılan boşlukları çevreleyen kendi özelliklerinin yanında, açılan yeraltı kazılarından dolayı farklı etkileşimlere maruz kalacaklardır. Bu nedenle, yeraltında farklı amaçlar için boşluk tasarımı yapacak olan mühendisler ve tasarımcılar, ilgili şartları değerlendirmek için kendilerinin yaratıcı düşünme dâhil, tasarım kabiliyetlerini geliştirmek zorundadır. Tasarımcıların orijinal düşünme kapasitelerini geliştirmek için ilk önce düşünülen, üzerinde yoğunlaşılan konu, yaratıcılık ve sanat olmaktadır. Mühendislikte karşılaşılan belirsizlik içeren veriler ve şartlar, mühendisleri farklı amaçlar için riskleri kabul ederek çözümler üretmeye zorlamaktadır. Kayaçlar içinde veya

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üzerinde geleceğe yönelik yaşanacak boşlukların (mekânların) tasarımı, yaratıcı düşüncelere sahip çalışanlara, mühendislere, bilim insanlarına, mimarlara, sanatçılara, tasarımcılara vb. ihtiyaç duymaktadır. Aslında, yeraltı şehirlerinin kazısı ve kullanım bilgileri; mağaralar, tüneller ve farklı amaçlar için açılan yeraltı madenlerinden elde edilen bilgiler ve deneyimler; bunları kullanarak kendi değerlendirmelerini, analizini yapacak olan yaratıcı tasarımcıların kullanımındadır. Bu bilgi ve tecrübelerin, kaya ve zemin mühendisliği bilgileriyle birleştirilerek değerlendirilmesi, yeraltı boşlukları düşünüldüğünde mühendislik açısından kullanımlı ve verimli tasarımların ortaya çıkmasını sağlayacaktır. Tasarımcıların hayal güçlerini ve orijinal düşünme yeteneklerini genişletme konusunda sanat ve sanat eğitimi önemli bir rol oynamaktadır. Sanatın ve sanat eğitiminin mühendislik yaratıcılığını geliştirme konusundaki katkısı değerlendirilerek bunun önemi vurgulanmıştır.

***Anahtar Kelimeler:*** *Sanat Eğitimi, Mühendislikte Yaratıcılık, Yaratıcılığın Geliştirilmesi, Yaratıcı Mühendislik, Sanat ve Yaratıcılık*

## Introduction

Why do we need to perform certain works to continue our life? In order to secure members of societies' lifestyles in countries, certain works should be performed at different times. Some of them are urgent, and some take time to complete. If a person has got open wounds due to unavoidable accidents, hospitals' emergency services are prepared for these urgent operations. Works and operations in these services need quick and correct decisions. Medical practitioners and operators should be ready and creative for numerous types of patient cases to cure them. Now think about the construction of a dam. Countries mostly have decisions to control rivers' water flow by constructing dams. According to its scale, procedures, and advancement, these constructions might have been taken for years sometimes. Decision steps in these kinds of rock-related works cover a wide range of uncertain parameters. Think about all the other human professions and imagine "decisions" supplied; some works are routine and require similar choices (modifications are not comprehensive) to continue. Some other professions like; mining, construction, machine, electronic manufacturing, etc., have required unique design senses. Companies have currently desired to employ engineers, architectures, designers, etc., for *real-world problems* of their projects, and they have mainly supplied limited periods for new engineers to adapt their projects' conditions. That means university graduates have to be good in designs, controls, organization, risk assessment of work and work-places, etc., for real-world businesses. Hypothetical and ideal problem-solving techniques have usually not worked in most engineering applications. Thus, decision circumstances could not be ideal for many different real-world cases. How should engineering faculty graduates feel their readiness for their professions then? This question has long been discussed for evaluation, and some universities have supplied their creativity enhancement curriculums (Gokay, 2020), in addition to students' STEAM (Science, Technology, Engineering, Art and Mathematics) based pre-university educations. Obviously, engineering decision conditions cannot be similar for two separate earth-crust locations. Those conditions cannot be the same for two man-shifts in industries. So, all the new products, machine models, excavated material properties, agricultural crops, etc., have been supplied carefully with handling different decisions. That means there are always some decision-makers and thinkers who should think, evaluate, arrange and produce critical decisions for real-world conditions.

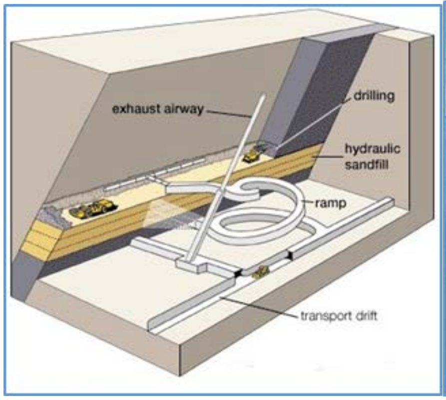
*Design* word in different professions represents a different meaning. Designing new products and models for existing types of machinery requires creative thinking in machinery, electronics, automation, etc. Similarly, designing streets, parks, depots, residential areas, and designing all required living volumes in constructions in/on rock masses cover more comprehensive skills and experiences. Think of a person who knows many subjects and supplies ready-to-apply solutions like encyclopedias or internet search engines. These types of engineers, architects, scientists, and designers are no longer favorable. Because internet search engines are available for the public to find state-of-art type solutions to common civil problems, some companies have already announced their prospective employees in engineering as creative decision-makers for their projects. These works might include state-of-art solutions for certain problems, but they have primarily included arbitrary and undefined problems which also cover uncertain real-world engineering conditions. For example, designers for underground excavations need to know what their planned usage is. They would like to know also how long they are going to be used. These and similar parameters have less ambiguity when they are compared to the decision supplied for failure conditions around these openings. Thus, rock mass conditions influencing decisions steps during the stability of dams, bridges, caves, slopes, underground openings, and rock foundations have risks due to uncertain rock mass parameters. Any structural failures in these engineering works create local or regional catastrophe and loss of many lives. Designing cities and living volumes for different social life integration have supplied valuable, efficient technology usage opportunities. Analyzing historic city plans (including underground cities) and problems that appeared in time (history) due to differentiating surrounding climates and other design features have put forward the requirements of new models, approaches. In addition, energy efficiency considerations and limitation requirements in carbon emission levels have started to force engineers and designers to behave in more creative ways in their new plans. Basically, underground living spaces need less energy to keep room temperature stable. However, they require energy for ventilation if “natural ventilation” is insufficient (when the air quality and airflow rates in these openings are lower than pre-described standards). Current living conditions in modern cities have pushed designers to supply new underground spaces for; shopping malls, parking areas, hotels, hostels, sports centers, agricultural crop depots, power stations, radwaste repositories, shelters for central computer systems, in addition to metro galleries and stations. The creativity of designers in this type of project should be integrated with mining and rock engineers’ skills and creativity to supply affordable and desirable spaces for modern societies. Moreover, it should not be forgotten that underground openings have their own risks of accidents. For all design opportunities, engineers and designers force themselves to widen their capacities in experiences, knowledge, creativity, original thinking, and imagination.

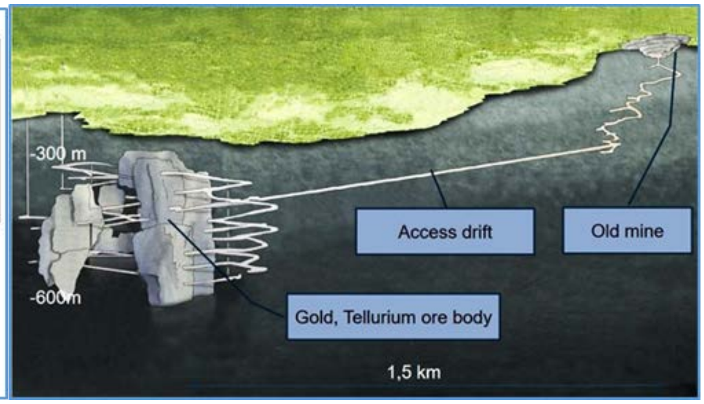
The underground city remains shown in Figures 1a, and 1b had been excavated and used for civil purposes. These underground spaces present ancient people’s lifestyles as well. Design strategies followed in similar underground cities have many clues about ancient human societies. Their engineering and artistic skills, their creative solutions for different human requirements in the underground have supplied opportunities to analyze their objectives in preferring underground cities for their daily life conditions. The graphical presentation, shown in Figures 1c and 1d, illustrates underground spaces. These are the artistic and graphical illustrations of modern mines. Usage of 3D graphical visualization (including engineering and artistic features) for underground spaces is an effective manner to present (and understand) underground volume types, their targeted aims, sizes, and positions with respect to each other. As given in Figures 1a and 1b, photographs could be taken with artistic considerations to visualize underground spaces in open-air conditions. If rock layers fully cover the spaces, these spaces can only be recorded by images taken from the insides. Tourists, observers, or artists might take many analogous photographs. Similar images record engineered structures' and cities' progressive situations in sequential periods, and these photographs' quality, value, and content have depended on artistic approaches. In some cases, their artistic and engineering requirements need to be combined for further analyses. Information about perspective, light and color balances, camera focus rates and view-angles, etc. are the governing factors. There are many photographs of cities, some of them are more artistic in characters. Logic, mind, creativity, original thinks, etc. (whatever it may be called), some people have different visual evaluation capacities to take photographs from different angles that influence other people more deeply. This is called photographic art. Artists have combined current photographs and virtual illustrations in computer graphics to present imaginary situations that are valuable for engineering education.

Educational documentaries (video films), which explain historical events, spaces, biological facts, atoms, molecules, Coronavirus in recent times, etc., have some form of imaginative virtual illustrations to explain scientific or engineered facts more comprehensively. Similarly, engineered 3D graphical illustrations of underground spaces have gradually become unavoidable requirements of underground operations. Virtual mine plans or virtual underground city plans which represent actual underground situations in 3D graphics are valuable assets for designers and engineers. If these virtual plans are reachable via "on-line" and equipped with "real-time" operational events (reported based on 3D-plan positions) like common weather software programs, they become main (internal usage) tools for mining and excavation companies. Artistic illustrations of underground spaces in different, visually attractive illustrations have progressively become priceless possessions of engineers, designers, architects, and scientists.

a)


b)



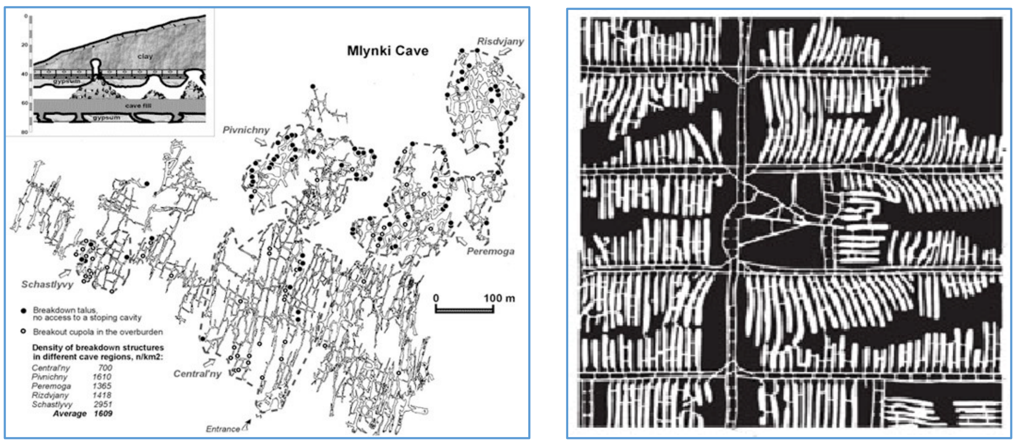




c) d)

**Figure 1.** a) Ancient underground city remains in Nevsehir, Turkey (BT, 2019); b) Caved homes of Guyaju, China (NH, 2021); c) Underground mining stope accessed with shaft and ramp (Hamrin, 1977); d) Underground mine plan illustration by Boliden (Bog, etal, 2017).

## 1. Design Thoughts for Underground Spacing

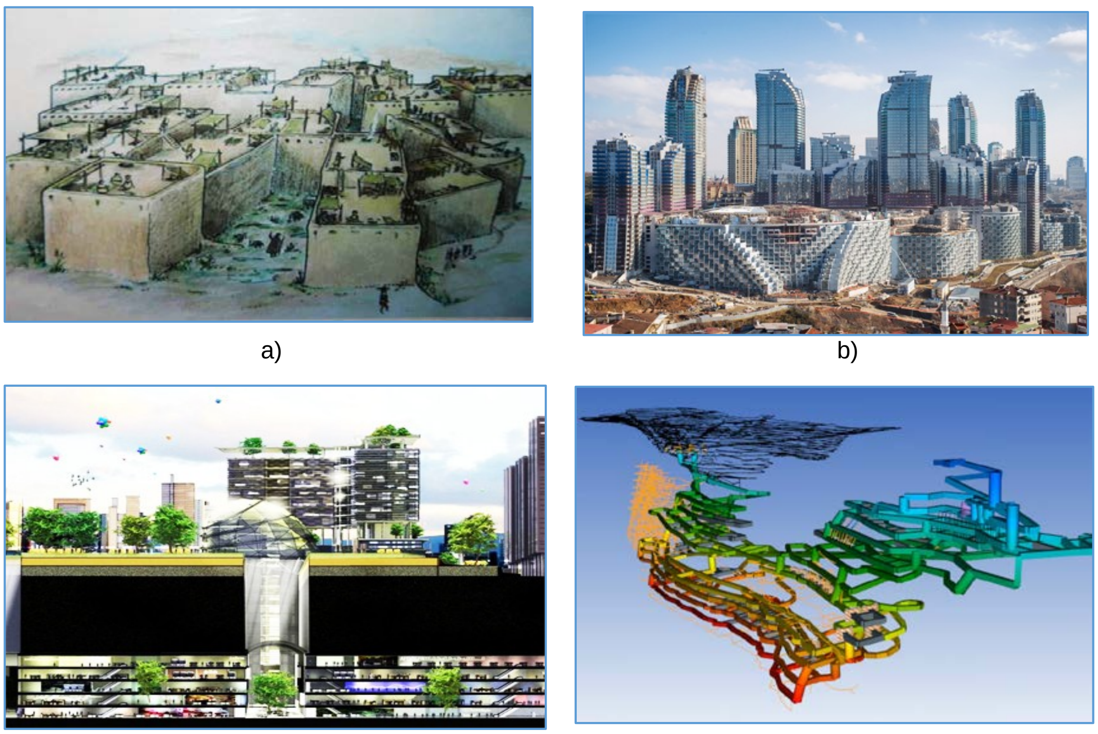
Usage of underground spacing for living purposes is not the new approach. Caves, small or big, had been early shelters for human beings since the beginning. Natural underground openings in rock masses could have been naturally initiated and expanded. Some of them have progressively collapsed due to high in-situ stress concentrations in surrounding rock masses (one of the reasons is the widened internal span and cave dimensions). Natural underground openings are usually discovered at rock masses' fault zones, fracture belts, or weakness zones. Their location in the earth's crust is entirely related to the rock masses' origin and tectonic features. The dimensions of caves have been differentiated (widened or constricted) due to 3D underground stress-strain conditions and groundwater movements. Limestone, gypsum, and salt rock masses could have huge underground caves and cave networks (labyrinths), including numerous dissolution features (Figure 2a). Manmade underground openings have probably been excavated in early times either for sheltering purposes (Figures 1a, 1b) or material extractions (Figure 2b). Coal and metallic ore mining especially, iron, copper, zinc, lead, gold, silver, had been the early reason for men who had developed experiences for underground ore mining methods. These ore and coal basins in the world have numerous abandoned underground spaces, gradually collapsing; however, some of the abandoned mine openings have still stable conditions, and they can be ready to be used for civil purposes. If there is a design project offered by central authorities to handle natural or manmade underground spaces for civil requirements, companies selected for design options should constitute work-teams counting creative engineers, architects, artists, designers, and scientists. These employees have their own experiences and knowledge to offer comprehensive opinions to have safe underground spaces for civil life requirements. Underground openings in different depths are costly to excavate. Due to 3D stresses originated by gravitational and tectonic forces, all locations in/on earth crust have differentiated gradually in time. Thus dimensions of underground spaces have been started to differentiate just after their excavations. Therefore, their dimensions must be decided carefully at the beginning according to engineering and aesthetic conditions and should be monitored continuously. That means designing, excavating, and monitoring excavation in/on rock masses include several factors, and these have been expanded as the designers' creativity widened. Think about architectural approaches for hotels, dormitories, office towers, residences, apartments, individual city houses, village houses, etc. for designing purposes (Figures 3a-3b); each engineering project has its targets and includes a wide range of options and parameters for design decisions (Figure 3) to compensate customers' comforts.




a) b)

**Figure 2.** Underground space networks; a) Map of Mlynki Cave (Ukraine) is presenting open passageways with collapsed locations (Klimchouk & Andrejchuk, 2003), b) Part of coal mine plan, it shows where are the underground coal pillars and mine galleries (black) and excavated stopes, spaces, (white) with their interrelating positions (Andros, 1914).

Underground spaces designed for selective projects (Figures 1, 2b, 3c, and 3d) also have their own design options. Design engineers should think about those design alternatives together with limitations governing by host rock masses in depths. People may have asked; Where are the arts of engineering and creative actions (critical thinking outputs, artistic aesthetics, art itself) in those design activities? At the beginning of any project, engineers, architects, designers, and artists have their blank page to draw preliminary sketches. These figures (2D or 3D) help designers to understand the problems and main resources. Experiences and knowledge captured from earlier projects are also valuable assets here. Original thinking capacity and designers' creativity are the main factors influencing projects' targets in current competitive engineering and architectural business areas. Artists, novelists, designers, architects, engineers, organizers, shop keepers, teachers, etc., (all types of professions) have their decision environments which based on "problem definition, pre-conditions, thinking on solutions, data collection, analyzing, evaluation, preliminary decision, monitoring, post-evaluation, final decision" steps. Professionals who are good in these procedures may add further creative manners to these steps according to their abilities. Employees who graduated from their schools by avoiding prototyping studies definitely positively impact their workplaces. Thus, education curriculums, including extra efforts for students' "creativity" and their "capacity enhancements", are "*the new normal*" of last decade's engineering education.



a) b)

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**Figure 3.** Design options for living and work-places; a) Catalhoyuk (Konya, Turkey) Neolithic village houses dated BC 7400-BC 6500. There is no window of houses and main entrances of them were at their ceilings (KST, 2021), b) High rise residences have been built in last decades in Istanbul-Turkey (TY, 2021), c) Illustrative design idea, "Next city " by G. Scruggs (Smithsonian, 2021), d) Underground mine galleries visualized in 3D-graphical illustration by using computer software (GDP, 2016).

## 2. Art Teachers to Enhance Wonderings

When the facts, information, knowledge, problems, and solutions are listed for a project through "*Five Ws and One H*", (Who, What, When, Where, Why and How) questions in an encyclopedic manner, students generally assume that most of the facts have their own explanations to follow. However, everyday decisions in human life are mostly given under uncertain circumstances. For instance, there is a standard laboratory test method to define mechanical properties of "*rock materials*". Such as, limestone rock samples have produced different mechanical values according to different earth locations.

However, this does not mean that these results can be used directly to define mechanical properties of limestone "*rock masses*", (limestone rock formations at certain positions of earth crust), because rock masses have large volumes and cover numerous discontinuities (fissures, cracks, faults), weakness zones, caves, etc. Then, decisions to describe the mechanical behavior of the rock masses have been supplied through evaluations of the whole subjects using engineering thinking and experiences. Rock mass ratings and related risk assessments, risk of failure for underground spaces, etc., are uncertain decision environments similar to decisions requested for earthquake risks and related damage potentials on constructions. There are no distinct definitions and limits yet (in deep knowledge of each profession); thus, engineering "levels" achieved in each profession mainly depend on detailed analyses, including experiences. Since there is no limit in learning and understanding the facts, engineers and designers should intensely concentrate on; their professional requirements, basic knowledge, and creative imaginations. Imagination governs men's wonderings, leading them to research and try to understand facts in detail. If some sub-parameters of the projected problems are not already described in the literature (printed ones including oral-history documents), employees of the companies (engineers, architects, designers, artists, etc.) in project groups have been expected to supply solutions. Imagination ability and its improvements are important issues for engineers (and the other employees), and art is the first concept. The starting point of all artistic products is generally thinking and sketching on blank paper (or; blank canvas, blank computer screen, etc.). Different products are then figured by the hands of artists governed by their training, education, knowledge, experiences, and creative minds. For example, paints in "still-life" and "landscape" classifications have images of plants and animals on artists' products with their actual appearances or illustrative presentation manners. Illustrations of actual visions of natural products, environments, countryside, and cities in 3D paints have fostered artists to illustrate imaginative visions as well. Illustrations of the human body and its interior parts in anatomy books, for instance, have been valuable assets for medical practitioners. Artistic approaches in 3D illustrations have usually covered more information (intentionally included) when they are compared to the actual case photographs. In some research subjects, having an actual case photograph cannot be taken. Everyday life includes many pictures shown in media as artistic illustrations (which have been prepared by using actual images or imaginary thoughts) like; illustrations of; atoms and electrons, solar systems, industrial products, futuristic city life, underground cave layouts, projected dams, and its environments, muscles, skeleton and human organs, etc. These figures, sketches, illustrations, and 3D models activate people's learning capacity and help them evaluate and understand the subjects. Thus, art and art education activities positively impact the imaginations and innovative power of people in societies.

People in art education are not just teachers who draw and paint in a technical sense; they must use their math, natural and social science knowledge to improve their students' creativities. Art education in current conditions has "great roles" in technology-oriented modern communities. Some students have been educated in STEM (Science, Technology, Engineering, and Mathematics) based education system. Some others have STEAM-based education, which "Art" is also added to their STEM curriculums before university education. Analyses of visual images and symbols surrounding societies through mass media could be performed using interdisciplinary studies. Art and artistic products are used to understand differences in visual forms of the same industrial products, such as; cars, trucks, spoons, forks, etc. When art teachers are lecturing about visual art subjects, different facts (information) and appearances (old and modern times' photographs, illustrations, graphics, etc.) related to the subjects should be supplied to students to enhance their understanding. What can be the facts influencing the creativity of engineers, architects, artists, designers, scientists, etc.? These professions might have produced solutions (plans, designs, maps, procedures, etc.) to obtain safe living and workspaces in/on earth crust. These facts can be explained as follows;

**a) Educational facts:** Improvements in students' imaginations and creative powers could be stimulated by interdisciplinary education. Parsons (1998, 2004) pointed that "interdisciplinary education" is related to "meaning and understanding". Students can work on different selected subjects to understand and use diverse information supplied by different disciplines. It has been expected that students should search the literature for their studies and then collect selective knowledge and relate them according to their aims. This is a methodology based on learning according to "understanding". In this learning method, "understanding the subject" is more important than the sub-levels of learning, such as "learning the subject" and "gaining routine experiences". Habermas (1981) had words for curriculum applications in the US. He said education was based on lecturing in different disciplines separately. According to him, an enhanced interdisciplinary education curriculum should be based on understanding life by combining gains from the disciplines. He stressed the school projects in which students have changed to express their manners. Popovich (2006) mentioned similar projected works for students include literature surveys and canvas paint products. In order to point out artists' capabilities, San's (2018) words are essential to mention here. She said that art had come closer to science and technology today and added that while watching the arts, the investigative sides of the artists, their dominance over technology, and their interdisciplinary study approaches have been standing out. Thus, education for design engineers, artists, architects, etc., should understand the subjects. Interdisciplinary education curriculums have been offered to cover physical and social sciences, including art disciplines to activate human minds and their original thinking. Artistic design thinking efforts especially have expected to enhance artists, engineers, and architects' creativity and imagination. Illustrative sketches, flow diagrams, x-y graphics, 3D graphics, virtual models, technical drawings, 2D plans, physical clay modeling, etc., have been practical tools provided by creative professionals to present their solutions in visual forms. Some societies have downgraded the importance of art-related activities and lectures in their education systems in the technology era, and they might have thought that art lectures were related to human feelings. Some people have assumed that art-related subjects require "less involvement in thinking", and these evaluations have still caused a misunderstanding of arts and its influence on human-oriented cultures and technology. It is significant to state what governs the professional imagination of engineers, scientists, and architects. Humans cannot be machines that work only for a routine job procedure. They live in different societies and cultures that have usually structured their minds and thinking environments; for example, education curriculums developed to enhance students' capacities in every aspect of science, technology, engineering, art, and math. (STEAM) cannot have similar graduates supplied by doctrine-based curriculums, which could be based basically on state-of-art types of knowledge and information.

**b) Brain capacity enhancement:** Human creative power has also been analyzed together with their brain capacities. General health science literature points that humans have a nerve system to control their bodies and brain functions. Kilic (2019), neurosurgeon, wrote that the main concerns about brain research have been concentrated on the research questions; *i) How does the human brain work and supply individual thinking ability? ii) How is consciousness supplied in the brain? iii) How brain supplies the mind?* Cajal (Nobel Prices winner in 1906) stated that human brain cells are separate units and that their connections and synapses form neural networking (Wikipedia, 2021). Herrmann (1989) mentioned thinking-types 30 years ago. He stressed human brains' synapses and the speed of actions among them. According to him, the human brain can supply creative new approaches (new developments, inventions) only if its synapses are well developed. At this point, Kilic's (2019) consideration can be mentioned here; he pointed that education is a kind of activity to form new synapses. He also stressed that "good teachers are the ones who lead their students towards the fields of sciences, beauties, hopes, and creative actions". Activating new synapses have been starting point to handle more capacitive and creative brains. Teachers who try to shape their students' behaviors and minds can enhance students' knowledge, imagination, and creativity. Besides the educational environments at schools and universities, visual cultures and environments observed in societies have also influenced people (and their brain synapses). Internet webpages, TV radio channels, symposiums, panels, all types of books, magazines, newspapers, etc., are the other "influencers" in current situations. Art teachers who teach how to "see" are governing instructors for students and people in the societies. Art teachers have supplied corrections and enhancements efforts wherever necessary in students' learning and understanding circumstances. Forming new brain synapses with structured visual knowledge, captured in daily life, is also important. Students can combine information supplied through social, political, economic, technological, and art-related features with new developments to analyze actual visual appearances around them. This action has required extra learning enthusiasm of students who would like to "understand" the knowledge around.

**c) Art stimulates creativity:** Art is supposed to reflect a human's inner world. When creativity is under consideration, the first subject that has often been considered is "art"; however, creativity approaches have involved all aspects of human activities like; scientific research, engineering, farming, industrial production activities, etc. Creativity research subjects include many sub-study areas, including; psychoanalysis, humanistic, Gestalt, observation, and brain capacity and synapses research. Many works, including early brainstorming stages, engineering plans, project evaluations, administrative presentations, activity organizations, etc., have been started to evaluate by drawing sketches, figures, and graphics to clarify ideas. Evaluation of problems has stimulated different ideas, thoughts, and concepts through scientific and artistic considerations. Art is handled here as a manner to express imaginations, ideas, original thinking, plans, and illustrations. Engineers, architects, designers, and artists have then facilitated their imaginations (Figure 4) with available physical resources to handle societies' demands (including workplaces in different industries). As far as tools, skills, materials, etc., engineers can design different procedures for diverse requirements. Art is a forcing aspect that deeply influences people's creativity to form extra capacity in their brains. Creativity can be found in different ranks due to their lifestyle, experiences, and educational background. Creativity can be enhanced or constricted. At this point, curriculums, including art education as one of the leading influencers (like STEAM), are very important for students to stimulate their creativity.

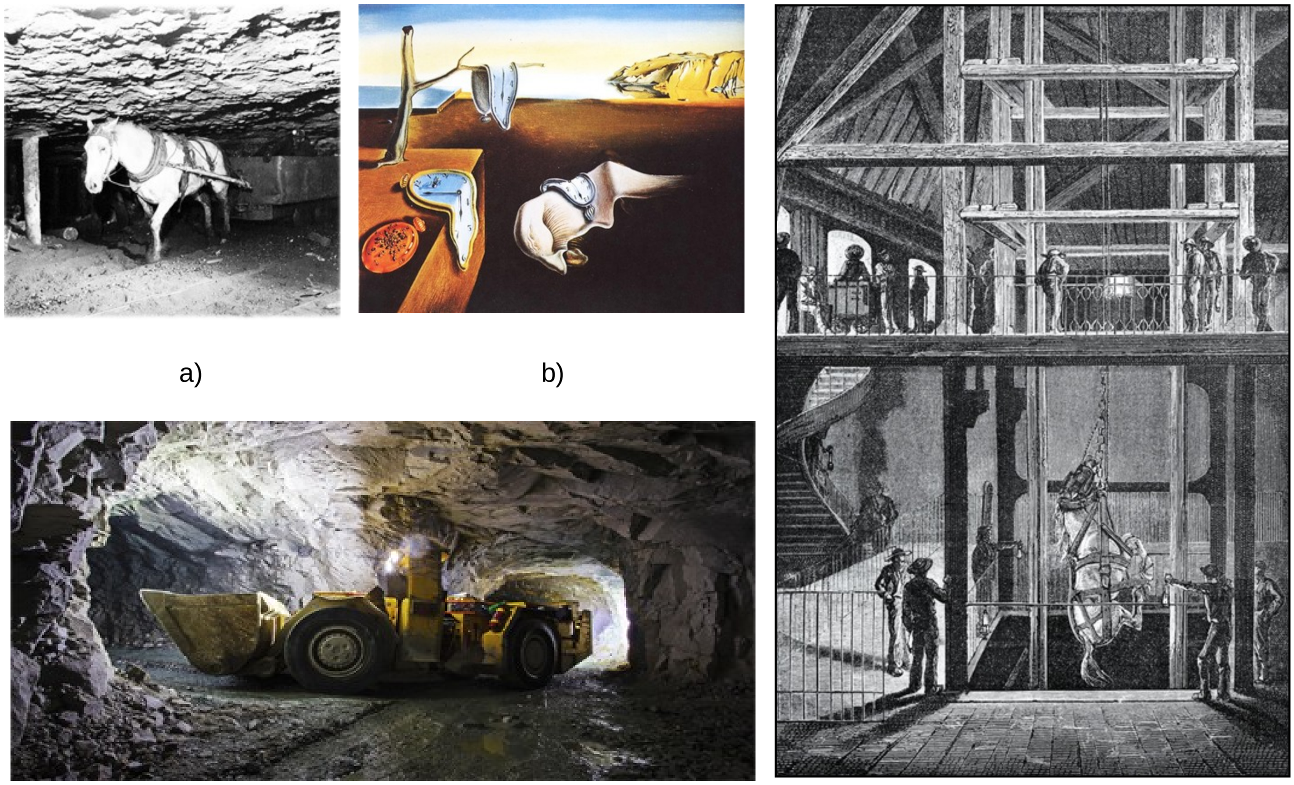

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**Figure 4.** Creative thinking products provided for different requirements; a) *"A pit pony and miner in a mine at New Aberdeen, NS, in August 1946. Photo: National Film Board of Canada/Library & Archives Canada/PS-116676"* (Evans, 2019); b) Persistence of memory, Salvador Dali, 1931 (WikiArt, 2021); c) Load-Haul-Dump, LHD machine in operation in modern underground gold mine (Hardline, 2021); d) "*An 1867 illustration of the apparatus used to lower a horse into a coal mine. Photo: Shutterstock/Marzolino"* (Evans, 2019).

**d) Creative activities:** Children have different activities to express themselves like; play, art, music, dance, sports, etc. Art itself provides extraordinary opportunities for children. Children can use their imaginative power throughout the art activities. In some cases, artistic thinking may supply new presentation types for their imaginative world by using common materials around them. Feelings and perceptions are essential concepts in human imaginations and their artistic products. In childhood, culture, activities, natural surroundings, information obtained from their parents, and surrounding knowledge and internet resources have shaped children's capabilities (increasing their brain's neuro-connections). Students have to be supported for their positive actions, and they should have opportunities to conduct studies for their wonders. They should recognize that they would like to "learn" more about the facts surrounding themselves. Education is a procedure for each member of societies (kindergarten children, schoolchild, adolescents, students at high schools and universities, postgraduate students, adults, etc.) and help people for their positive evaluations. Thus, all the students at the beginning are advised to improve their knowledge and artistic abilities to direct their creative thinking powers.

## Conclusions

Engineers who work for underground spaces have to enhance their understanding of 3D volumetric space. Besides their excavation plan ability, they must present some abilities of city-planers and architects, like rock and mine engineers. Designing volumes, passageways, galleries, stopes, hotels, stations, shelters, etc., in/on rock masses require creative thinking to produce efficient engineering outputs. Underground spaces have opened mainly for ore excavation (openings are by product of the operation if they are not caved) and civil purposes (openings are purposely excavated in the plan to use). Engineering and art have combined to understand human nature and requirements. Art has also been reported as an essential activator of human original thinking. New understanding and dimensions in science, engineering, and art need diverse thinking abilities; thus, education curriculums that have facilitated "*original thinking abilities*" instate the reputation of "*earlier knowledge and information*" are valuable assets. At this point, it is significant to note that art education has supplied a different understanding to people. Creative fine-art products in museums; supplying any kind of artistic products which include originality; new design of automobiles and constructions, cities, dams, bridges, mines, airplanes, etc. cover detail works of design efforts in different professions. Creativity is a common subject mentioned in all engineering cases. Graduates of engineering faculties have re-discovered the influence of art and its thinking contents in engineering. Ancient civilization ruins have many hints of creativity, artistic imagination, and engineering considerations together. Imagination is the basis of many engineering inventions; therefore, art education cannot be considered just for students in social science professions. It should be supplied for students in science, engineering, and medicine. Art itself and artistic thinking help people to enhance their imaginative powers. Thus, art and art education should be branches under consideration also in engineering education. Leading engineering companies have supplied their intention to hire creative graduates in a ready-to-act state. Therefore, some engineering faculties have adjusted their curriculums accordingly to approach new understandings in engineering education.

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