STRATEGIES, METHODOLOGIES AND ANALYSIS

PREPARING TEACHERS TO APPLY A STEAM APPROACH THROUGH THE APPLICATION OF THE GOLDEN RATIO

STEAM ing ahead

Fostering critical thinking, problem-solving and creativity

JUNE 2022

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Table of Contents

I. STEAMING AHEAD PROJECT: MOVING THE STEAM APPROACH FORWARD THROUGH TEACHER-LED COOPERATION

I.1 CONTEXT AND APPROACH

While STEM (Science, Technology, Engineering and Mathematics) initiatives are a wonderful start into the exploration of these four areas of study, the critical process of creativity and innovation is missing. STEAM programmes add 'Art' to a STEM curriculum by drawing on reasoning, ethics and design principles and encouraging creative solutions.

Using STEAM education instead results in students who take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process, potentially becoming the innovators, educators, leaders, and learners of the 21st century.

Image 1. Photo by MART PRODUCTION from Pexels

STEAM programmes, as a repurpose for STEM, aim to teach students innovation, to think critically and use engineering or technology in imaginative designs or creative approaches to real-world problems framed in social studies.

Our motivation lies in our conviction that STEAM is currently showing that it is an essential development of STEM, making the intentions within STEM more accessible while also fulfilling enhanced access to key competences.

Partners are motivated to seek out new and innovative ways to nurture the key competences necessary for employability, personal fulfilment and health, active and responsible citizenship, and social inclusion.

We identify key competences as those which all individuals need for personal fulfilment and development, employability, social inclusion, sustainable lifestyle, successful life in peaceful societies, health-conscious life management and active citizenship.

We recognise there is a need for them to develop in a lifelong-learning context, from early childhood throughout adult life, and through formal, non-formal and informal learning in all contexts, including family, school, workplace, neighbourhood, and other communities.

The project Partners in STEAMing Ahead believe that the European Reference Framework on Key Competences for Lifelong Learning is a touchstone, a vision in educational thinking as everyone does have the right to high quality and inclusive education, training, and lifelong learning in order to maintain and acquire skills that enable them to participate fully in society and manage successfully transitions in the labour market.

We note the European Reference Framework on Key Competences for Lifelong Learning[1] has identified the following eight key competences:

1. Literacy competence.
2. Multilingual competence.
3. Mathematical competence and competence in science, technology, and engineering.
4. Digital competence.
5. Personal, social, and learning-to-learn competence.
6. Citizenship competence.
7. Entrepreneurship competence.
8. Cultural awareness and expression competence.

We believe that everyone has the right to timely and tailor-made assistance to improve employment or self-employment prospects, and that this includes the right to receive support for job search, training, and re-qualification. These are principles that are defined in the European 'Pillar of Social Rights'[2].

In a rapidly changing and highly interconnected world, each person will need a wide range of skills and competences and to develop them continually throughout life. The key competences we identify aim to lay the foundation for achieving more equal and more democratic societies.

They respond to the need for inclusive and sustainable growth, social cohesion, and further development of the democratic culture. We see a STEAM approach

[1] European Reference Framework on Key Competences for Lifelong Learning.

[2] The European Pillar of Social Rights in 20 principles.

to this challenge as a key that will unlock an enormous potential in young people and prepare them to embrace lifelong learning with enthusiasm rather than fear that it as an indicator of economic insecurity.

We believe that STEAM-based activities similar to those we propose can support efforts at European, national, regional and local level to foster the development of knowledge, skills and attitudes in a lifelong learning perspective.

For this, we identify knowledge as comprising the facts and figures, concepts, ideas, and theories which are already established and support the understanding of a certain area or subject.

We see skills as the ability and capacity to carry out processes and use the existing knowledge to achieve results, and attitudes as describing the disposition and mind-sets to act or react to ideas, persons, or situations. STEAM has the potential to have a direct impact on all these elements, for the benefit of both individual learners and the communities they inhabit.

I.2 OBJECTIVES AND THEIR CONNECTION TO PRIORITIES

Our objective is to use a universal study-subject as a theme that has direct relevance to a STEAM approach and use it to stimulate virtual cooperation and experimentation with virtual and blended learning opportunities.

This will include the use of eTwinning platform, the School Education Gateway, and the Electronic Platform for Adult Learning in Europe (EPALE) as a network infrastructure to facilitate working together before, during and after the project activities.

I.3 THE STEAM APPROACH

The Universal study-subject we have chosen is the Golden Ratio, naturally including all references to the Golden Rectangle as a constant feature throughout the history of Art. It has been chosen for its relevance to all the original STEM subjects, while drawing on reasoning, ethics and design principles and encouraging creative solutions, inserting the meaning of the STEAM distinction.

Our objective is for the development of a comprehensive, broad yet detailed set of pedagogical resources based around the Golden Ratio, resulting from an in-depth STEAM approach, using all elements of the Golden Ratio, will then be accessible for schools across those countries in the EU and the other Erasmus+ Participating Countries.

We think that from confidence in the knowledge, skills and attitudes that connect with the Golden Ratio in the context of a STEAM approach to learning will assist in stimulating students in line with the aims of STEAM.

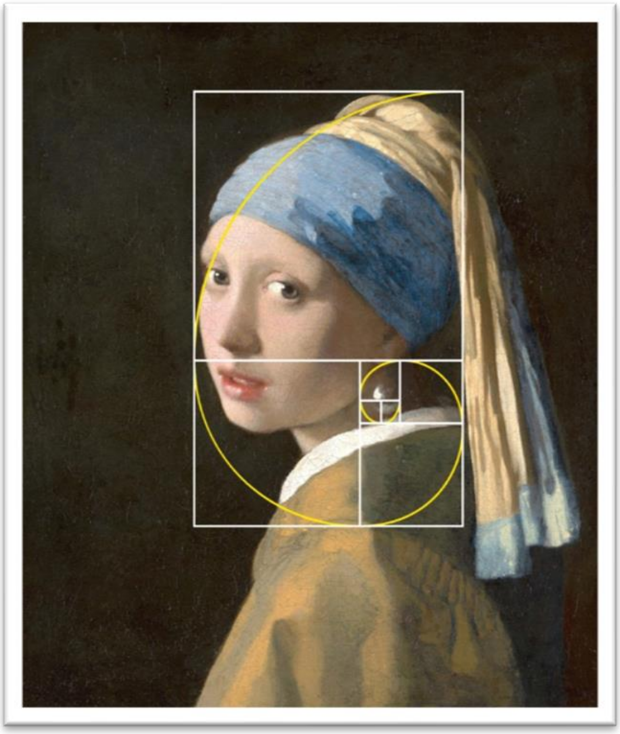


Image 2. Girl with a Pearl Earring by Johannes Vermeer

The objective is for students to take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process, potentially becoming the innovators, educators, leaders, and learners of the 21st century.

The Golden Ratio also carries universality, so that it will be ideal for stimulating cooperation across borders among the Partners. Though not identified in our list of Priorities, we are committed to supporting teachers, school leaders and other teaching professions as an objective.

In the context of this work, we feel the Golden Ratio can stimulate individual thinking among all the teachers who are active participants in the work of the project as well as stimulating lively discussion in meetings and virtual settings to improve pedagogical ideas and stimulate new approaches.

I.4 KEY COMPETENCES

The project has an objective to develop results that support the acquisition of key competences as set out in previous sections, presenting them in a form that reflects the equality of their importance while also respecting the most direct connections to each of those competences through the Golden Ratio.

STEAMing Ahead will address their acquisition at various points of the project's implementation. We believe that each of the competences contributes to a successful life in society. We recognise that competences can be applied in many different contexts and in a variety of combinations, that they overlap and interlock; aspects essential to one domain will support competence in another.

Skills such as critical thinking, problem solving, teamwork, communication and negotiation skills, analytical skills, creativity, and intercultural skills are embedded throughout the key competences. They are embodied in the purpose of the STEAM approach, and we see the Golden Ratio as an ideal platform to launch practical activities in the classroom that will further the attainment of key competences and deepen our understanding of STEAM's potential.

In the context of key competences as defined in the Reference Framework, we want the work of our project in deepening the effectiveness of a STEAM approach to have an impact on policy makers, education and training providers, educational staff, guidance practitioners, employers, public employment services and learners themselves.

I. 5 SUPPORTING TEACHERS

The work on the project will be guided by the needs within the teaching profession for experience and a broad range of capacities that will better enable the implementation of a STEAM approach in secondary schools within Europe.

We have an identified objective to enhance teachers' continuous professional development, first within the three secondary schools that are Partners within STEAMing Ahead. However, beyond this we seek to network widely so that other schools can be engaged with our activities increasingly as the activities are carried out and then especially at the end of the project through the results gained.

By raising the profile of the STEAM approach through innovative and collaborative work, we seek to make teaching careers more attractive and diverse by opening doors to new, exciting pedagogies where teachers can be confident that they are helping to meet the needs of their students currently and in later life.

We believe that the activities proposed here will support the development of stronger school leadership among teachers, with a more confident and visible application of the STEAM approach in schools.

We hope that the results of work will supply resources that teachers can use in the classroom, but also in making proposals for strategic development in the rooms where policy is decided. This confidence will come in part from a practice of the innovative methods behind a fresh STEAM approach as well as innovative methods of assessment.

Image 3. Photo by Max Fischer from Pexels

I.6 DIGITAL DIMENSION

Especially in the context of the COVID-19 pandemic that has affected schools across Europe so deeply since the beginning of 2020, the Partners are committed to embedding virtual cooperation and experimentation among the teachers as they develop and innovate on the precise details of their STEAM approach to applying the Golden Ratio as a core teaching theme in their own school settings.

Equally, the project will take full advantage of virtual and blended-learning opportunities that we see as being crucial to the success of our partnership. We are conscious that the value of the results that we will produce lies in extensive exchange across international borders between the schools.

We also know that this digital dimension in our work will encompass extensive use of virtual environments within the project communications between Transnational Meetings.

For ensuring that our results are valuable to target groups, beneficiaries, and other stakeholders beyond the boundary of our project, we will embrace eTwinning, the School Education Gateway, and the EPALE Platforms, facilitating collaboration before, during and after the project activities.

I.7 TARGET GROUP

School teachers specialising in Art or Science – Local/Regional/National Teachers in the classroom must be convinced that STEAM has efficacy and effectiveness in the learning process so that they can adopt the STEAM approach with conviction.

School students – Local/Regional School students are essential participants in the work of the project, especially during the pilot and curriculum application. It is valuable that they have a good understanding of the purpose behind STEAM so they can self-motivate for activities that they are set in the classroom then advocate to their social networks and peer groups.

II. PROJECT PRODUCT NUMBER 1: STRATEGIES, METHODOLOGIES AND ANALYSIS

Preparing teachers to apply a STEAM approach through the application of the Golden Ratio

(M1–M9). Leading Organisation – Make It Pedagogical

Output Types:

1. Methodologies / guidelines — Pedagogical strategy.
2. Methodologies / guidelines — Methodological framework for implementation.
3. Studies / analysis — Case study.
4. Learning and teaching material — Guidance material.

The first seven months were dedicated to setting out the strategies and methodologies that can be used in the three schools, including the analysis that supports the documentation and resources produced.

This was the time for the most intensive work done on the pedagogy, and where there will be less direct work with students in the classroom as this will be higher once the new school year starts in M10. The schools will work directly with the other project Partners as the work is produced to assist in preparing the teaching staff for implementation.

II. 1 TEACHER-CENTRED VS. STUDENT-CENTERED EDUCATION

In **teacher-centered learning** — the more traditional or conventional approach — the teacher functions in the familiar role of classroom lecturer, presenting information to the students, who are expected to passively receive the knowledge being presented.

In the teacher-centered model, the teacher as the expert in charge of imparting knowledge to his or her students via lectures or direct instruction. In this setting, students are sometimes described as "passive" listening to and absorbing information.

Though the teacher-centered method is historically considered the more traditional approach, the education field has evolved to recognize the significant benefits of empowering students to be more active participants in their own learning. However, there continue to be countless examples of students being challenged and transformed by a teacher lecturing about a subject they have spent their entire life exploring.

In **student-centered learning**, the teacher is still the classroom authority figure but functions as more of a coach or facilitator as students embrace a more active and collaborative role in their own learning.

The student-centered model builds more stability between the teacher and student, with each playing a role in the learning process. The teacher is more of a facilitator, coaching students and assisting them in their learning.

This approach champions student choice and facilitates connections among students, embracing the philosophy that, for students to learn truly, they must be actively involved in the process.

Many teachers strive to implement a blend of teacher-centered and student-centered styles – sometimes within the same classroom – based on their own instincts, research and experience.

II.2 IDENTIFY THE KEY ELEMENTS THAT ENABLE WORK ACROSS ARTS AND SCIENCE

Today, the relationship between art and science in our society is more complex: Although artists and scientists are both driven to observe and create, they largely reside in different cultural spheres—sometimes brought together serendipitously, other times intentionally. It is impossible to generalize relationships between art and science since neither is a fully defined nor homogenous category.

Art and science have coexisted, often indistinguishable from each other, across time and space. A wealth of early documented examples comes from the Islamic culture, where art and science joined in intricate star-shaped architectural geometries, and the use of "Nur" (light) and material science to design utensils and lettering in manuscripts.

During the Renaissance, the Italian polymath Leonardo Da Vinci was simultaneously a painter, sculptor, engineer, botanist, and scientist. Indeed, the term "Renaissance man" would come to be synonymous with a person with many talents and knowledge.

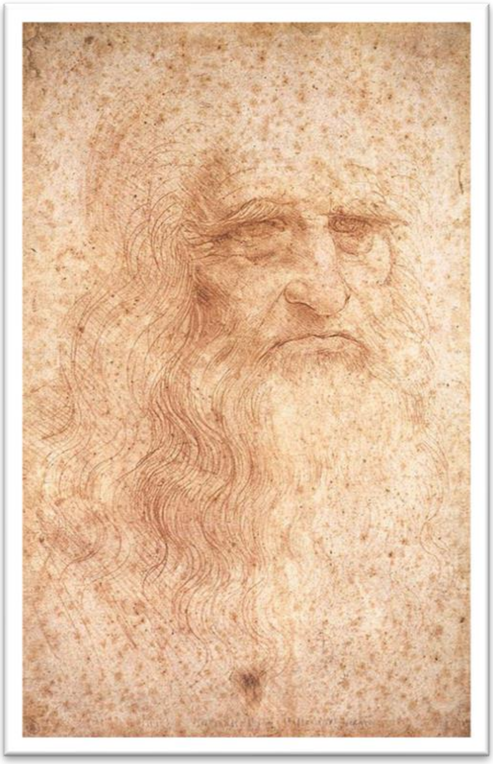


Image 4. Portrait of a Man in Red Chalk, by Leonardo da Vinci

The separation of art and science into different cultures in the West took place during the 19th century, which incidentally or consequently coincides with coining of the term "scientist" in the mid-1800s. Both disciplines share their origins in the representation and interpretation of nature, but, over time, their methodologies diverged, and the scientific school of thought became largely driven by specialization and hypothesis-based inquiries.

Art, in turn, developed its own schools and methods, from classical art, which tended to observe and imitate nature, to branches of impressionism, cubism, and expressionism. Nonetheless, there are many places of convergence between the two, both in the past and today.

During the Renaissance, sketches of plants, animals, human anatomy, and stars done in lieu of cameras were not just beautiful pieces of art, but also forms that required extraordinary technique and skill to communicate their observations. Beyond these pieces is an idea that is central to both art and science: the primacy of observation and interpretation.

As Peter W. Parshall and David Landau write in The Renaissance Print: "Accurate visual representation was more than just a technical accomplishment. It was a highly specialized form of observation… Making illustrations was a way of checking facts, and by mid-century it was being supported by other means as well.

Public and private botanical gardens were being planted, and collections of dried specimens were being assembled into herbaria. In such a climate the illustrated herbal was bound to become the standard point of reference for scholars attempting to devise different schemes of classification".

There are many examples of how art and science intermingled based on observation and interpretation, ranging from a physical object based on both engineering and artistic design to an informative visual piece that acts as a communication tool.

An example of the former is one of the world's architectural marvels, La Sagrada Familia, which Antoni Gaudí designed and started building in Barcelona in 1883. Gaudí was inspired by geometrical features found in nature and used his observations of nature's organizing principles to design the physical structure of the church.

Gaudí himself said, "I am a geometrician, meaning I synthesize" (from La Sagrada Familia website). This approach is reflected in the unique branching tree columns and staircases with seashell-like curves placed through the church.

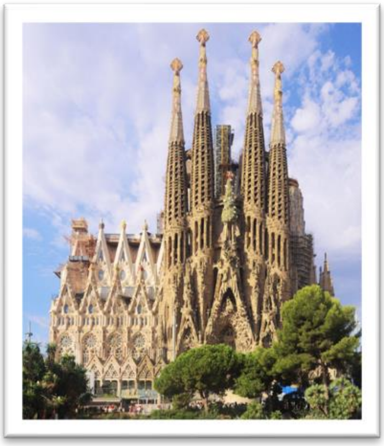


Image 5. The Sagrada Família Basilica, by Antoni Gaudí

Art and science both render ideas about the world into a form that allows the viewer to connect to the idea. An observation, whether of a spider, a cell, or human nature, is necessary, but not sufficient to result in a meaningful work of art or a scientific finding. It is the interpretation, the focusing of the camera lens, the telling of a story, the choice of what part of the observation will be rendered and explicated, that gives life to it.

This interplay underlies much of the modern scientific methods and processes of art, as both artists and scientists do not comprehensively copy, but rather interpret and curate what they see into something meaningful and relevant.

The line that separates art and science in the modern age remains a superficial one; at the core, artists and scientists observe and interpret the world around them, though they may use different methods and expressions. This artificial cultural divide is prevalent in our society, but some visionaries and institutions are consciously bridging it.

For instance, medical schools are beginning to incorporate art into their curriculum. In fact, there is evidence that the use of art can help medical students "apply their observational and interpretive skills" and "accept the facts that ambiguity is inherent to art, life and clinical experience and there can be more than one answer to many questions" (Kemp, 2005).

An important feature of the modern merging of art and science is the understanding and communication of abstract and higher-order ideas. Like Merian, who communicated her observations of insects and plants using sketches, Tadashi Tokieda, a mathematical physicist at Stanford University, creates artistic demonstrations of abstract mathematical concepts.

Tokieda, a painter and mathematician, uses his unique background to create elegant toys that not only demonstrate exciting, realizable phenomena from his research, but also help to develop new hypotheses.

Image 6. Painting of a coronavirus, by [David S. Goodsell]

David Goodsell, a structural biologist at The Scripps Research Institute, uses watercolors and computer-aided illustrations to present the world of cellular structures and molecules. His work gives access to the nanoscale structures of life that would otherwise be invisible to human eye (Williams, 2017).

Reciprocally, artists also use abstract scientific drawings and concepts to create art. The steel sculptures by

Edward Tufte, a pioneer of data visualization techniques, are not only "abstract glinting art", but much like historical sketches of organisms and stars, also an accurate representation of physical principles, including some that are inspired by the diagrams of Richard Feynman.

Another dimension of the contemporary integration between art and science is the use of technology. Digital tools have not only become a popular platform to create and share art but are also driving technical improvements.

Similarly, recent developments in semi-automated computational platforms (Spinney, 2018), allow to create and dynamically revise illustrations of natural processes based on new findings. This approach is likely to accelerate the pace at which society at large learns new concepts.

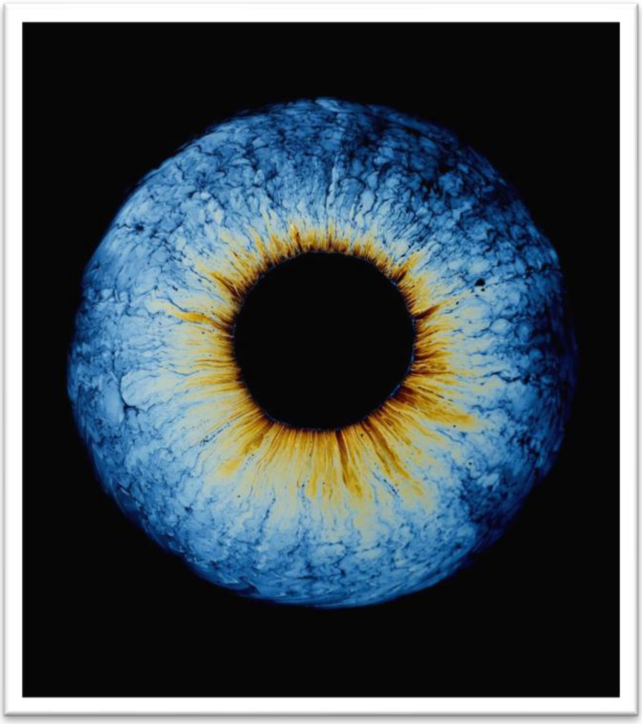


Image 7. Oil Spill, by Fabian Oefner

More advanced applications of technology in the art include the use of artificial intelligence (AI)-based robots as a tool. Interestingly, this has led to a current debate (Spinney, 2018), as to whether such technologies can work autonomously without the intervention of artists themselves.

The collaborative efforts of contemporary science and art can also have important consequences for society through enabling communication of ideas and access to nature. For instance, similarly demonstrations and videos of mathematical concepts as well as Goodsell's illustrations of protein structures are freely available on the Internet.

The work of Fabian Oefner, a Swiss artist, who uses scientific concepts including electricity and magnetism to engineer beautiful time-lapse art, is the flip side of the same coin. Oefner makes scientific concepts accessible to a broader audience by making "the invisible effects of the natural sciences known".

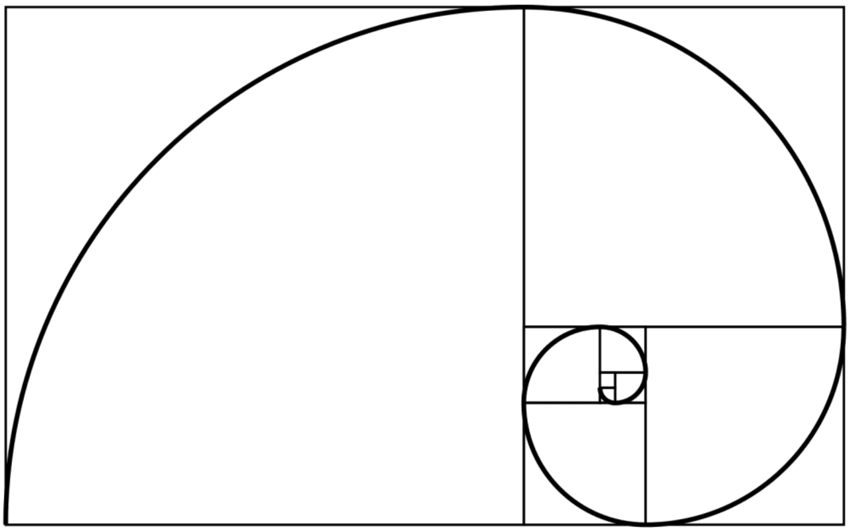
In addition to addressing access to science, these collaborations can also touch on global and societal issues including climate change, migration and displacement, diseases, and pollution. In these endeavours, whether through photography, recycled waste, glass work, metal scaffolds, or knitting patterns, science and art jointly turn to pressing issues and present creative solutions.

III. IDENTIFY THE QUALITIES IN THE GOLDEN RATIO AS A SUBJECT AREA APPROPRIATE TO A STEAM APPROACH

III. 1 WHAT IS THE GOLDEN RATIO?

The golden ratio, also known as the golden section, golden proportion, or the divine proportion is a mathematical concept that is one of the most famous examples of connections between mathematics and the arts (Dana-Picard et al., 2021).

The golden ratio is a ratio between two numbers that equals approximately 1.618 (Olsen, 2018). Usually written as the Greek letter phi, it is strongly associated with the Fibonacci sequence, a series of numbers wherein each number is added to the last. The Fibonacci numbers are 0, 1, 1, 2, 3, 5, 8, 13, 21, and so on, with the ratio of each number and the previous number gradually approaching 1.618, or phi (Olsen, 2018).



The first known mention of the golden ratio is from around 300 BCE in Euclid's Elements, the Classical Greek work on mathematics and geometry (Olsen, 2018). Euclid and other early mathematicians like Pythagoras recognized the proportion, but they didn't call it the golden ratio. It wasn't until much later that the proportion would take on its mystique.

In 1509, Italian mathematician Luca Pacioli published the book 'De divina proportione', which, alongside illustrations by Leonardo da Vinci, praised the ratio as representing divinely inspired simplicity and orderliness (Olsen, 2018).

Because of Pacioli's book and Leonardo's illustrations, the golden ratio gained fame among mathematicians and artists. In the centuries since Pacioli's book, many enthusiasts have claimed that the number is naturally pleasing to the eye, that it is a mathematical distillation of beauty, and that golden ratio line segments, golden rectangle side lengths, and golden triangles are represented throughout art history.

Golden ratio enthusiasts argue that the golden ratio is aesthetically pleasing because it's common in the natural world. The proportions of nautilus shells and human bodies are examples of the golden ratio in nature, but these tend to vary greatly from one individual to the next.

Some seashells expand in proportion to the golden ratio, in a pattern known as a golden spiral, but not all shells do. It's true that nautiluses maintain the same shell proportions throughout their life, but the ratio of their shells is usually a logarithmic spiral, as opposed to an expression of phi.

Phi does show up in other aspects of nature. Tree leaves and pinecone seeds tend to grow in patterns that approximate the golden ratio, and sunflower spirals and other seeds tend to hew close to phi. Phi allows for efficient distribution or packing, so leaves that grow in relation to the golden ratio will not shade each other and will rest in relation to one another at what is known as the golden angle

There's no evidence that use of the golden ratio is better than use of other proportions, but a few artists and designers have deliberately based their work

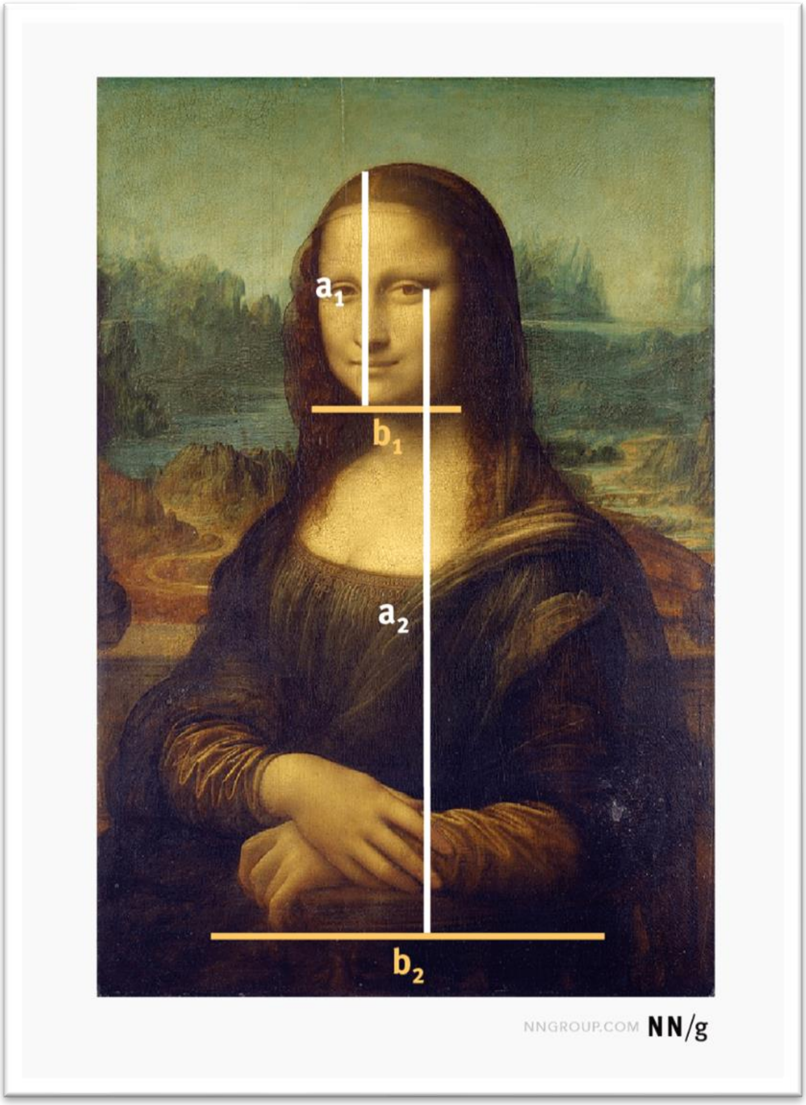


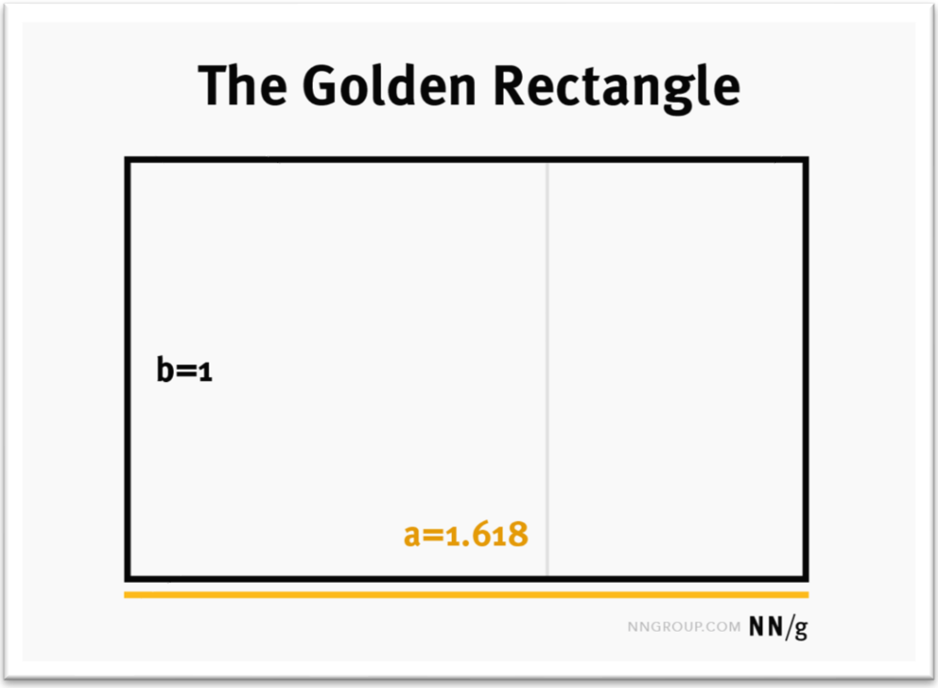
Image 8. Leonardo Da Vinci's Mona Lisa: The length and width of the head (segments a1 and b1), as well as the length and width of the torso (starting from the eyeline down to the hands — segments a2 and b2) are in golden ratio.

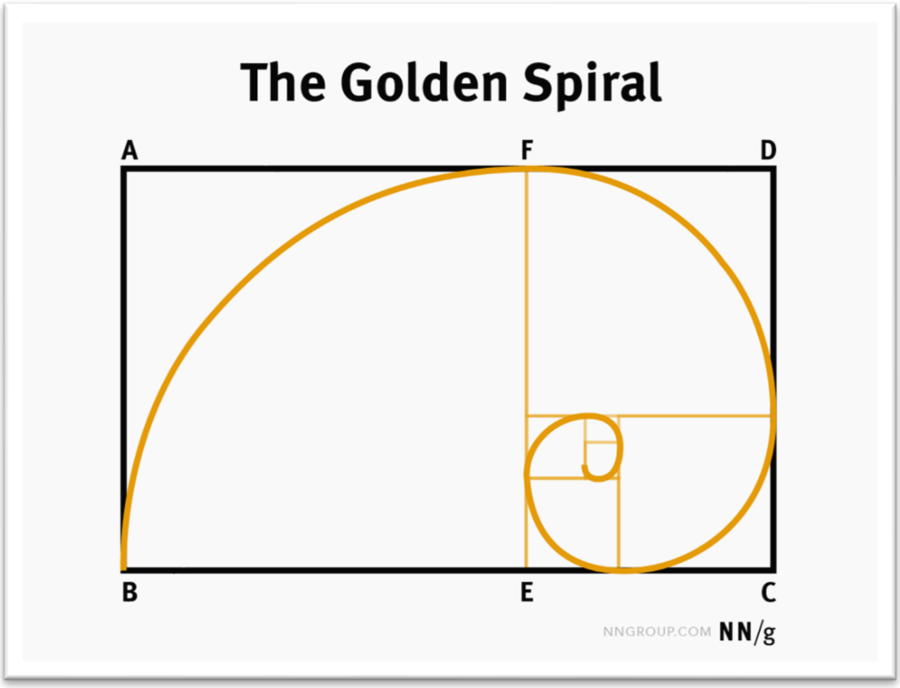
around the golden ratio. Le Corbusier, a famous mid-century modern architect, based a good deal of his architectural system around the golden ratio. Salvador Dali, the surrealist painter, intentionally used a canvas shaped like a golden rectangle for his painting The Sacrament of the Last Supper.

Art historians have found other examples of the golden ratio in the Mona Lisa, the Parthenon in ancient Athens, and the Great Pyramid of Giza. However, most of the time there is no explicit evidence that artists intentionally used the ratio the way Le Corbusier or Dali did. Without design notes or specifications for the pyramids, we can't know if ancient engineers employed phi on purpose.

III.2 HOW TO USE THE GOLDEN RATIO

Aesthetics and design don't adhere to strict mathematical laws. You can create a poor design that still conforms to the golden ratio, but you can use the golden ratio to inform your composition, to help you avoid clutter and create an orderly and balanced design. You can use the golden ratio to help guide you: "On a graphic that might be pretty busy, so placement is everything" (Dana-Picard et al., 2021).

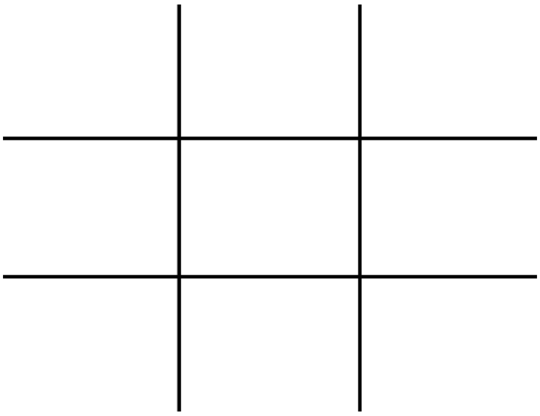


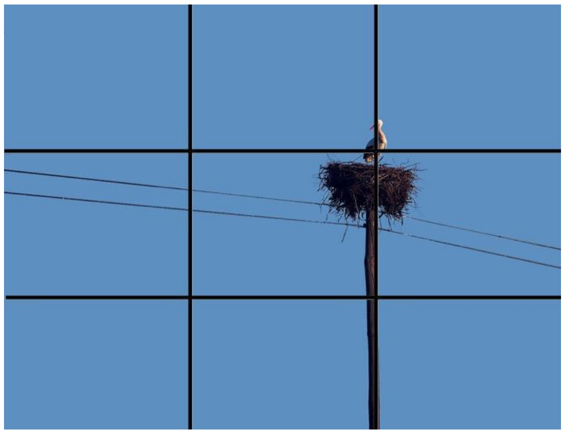


The golden ratio can work a bit like the **rule of thirds**. It can be a compositional convention or guide, but not a hard-and-fast regulation about how you should structure your work. Ultimately, spacing is important and any kind of guideline is helpful. If you just center every image or arrange text as a single unjustified block, you risk alienating your reader, viewer, or user. Use the golden ratio as a guideline for your work to make sure things are nicely spaced out and well composed.

III. 3 WHAT IS THE RULE OF THIRDS?

The rule of thirds is a composition guideline that places your subject in the left or right third of an image, leaving the other two thirds more open. While there are other forms of composition, the rule of thirds generally leads to compelling and well-composed shots.





If you imagine dividing a photo, or even your camera's viewfinder, into nine equal zones using horizontal and vertical lines, that forms your rule-of-thirds grid — a setting you can select on most cameras and even on your smartphone.

That means the corners of the central square are the intersection points in your grid where you want to place the focal point of your shot. It's called the rule of thirds, but you can think of it as giving you four crosshairs with which to target a shot's important elements. This will help you balance your main subject with

negative space in your shot to nail an effective photographic composition that will draw the viewer's eye.

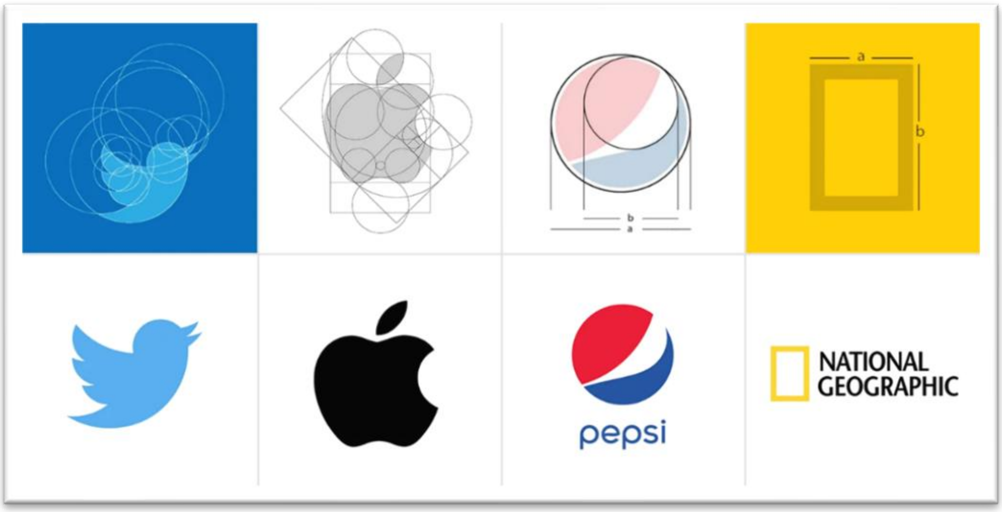
III. 4 APPLICABILITY OF THE GOLDEN RATIO IN DESIGN

Even though there will never be a one-size-fits-all approach to design, the Golden Ratio is a practical, mathematical technique that can help us get closer to consistently producing wonderful design experiences. When applied to design specifically, the Golden Ratio creates an organic, balanced, and aesthetically pleasing composition.

The golden ratio rule has achieved the status of common knowledge in art and design. The use of the golden ratio is not rarity even in design of today's industrial products and it is proved that those rules contribute to improvement of aesthetic impression that a product can have on potential consumer (Hsiao & Chou, 2004) (Disneya et al., 2004) (Bloch, 1995) (Noble & Kumar, 2010) (Khalid & Helander, 2006) (Crilly & Clarkson, 2004).

In graphic design, for example, the Golden Ratio can be used to guide designers in choosing typography sizes and hierarchies, to create harmony in image composition, to sizing and cropping images, to manage the placement of elements in a layout, to design user interfaces and websites or to create a logo.

'Golden shapes' like triangles, squares, circles, and spirals are widely used while designing an icon or logo. Proper use of the golden shapes can harness a proper balance and can turn a good design to a great one. As you can see, many popular logos follow the Golden Ratio.



IV. TOWARDS A METHODOLOGICAL FRAMEWORK

Although it is not common to perform a Systematic Review in fields other than Health, its value in Education is indisputable. With the increase of research and its generalised availability, how to decide what is relevant and scientifically sound? How can decision makers and professionals keep up with the advances in their fields?

In this **Project Product number 1: Strategies, Methodologies and Analysis**, we argue that a "systematic review methodology is accepted as a research methodology in its own right" (Boland et al., 2014, p. 9), which is "designed to locate, appraise and synthesise the best available evidence relating to a specific research question to provide informative and evidence-based answers" (Boland et al., 2014, p. 3).

As so, it was decided to perform a systematic review as a methodological approach to state of the art (Gough, Oliver, & Thomas, 2012) following an adapted version of Boland et al. (2014, p. 10) proposed 9 steps.

Systematic reviews follow well-defined and transparent procedures and always require the following:

- **I.** Definition of the question or problem.
- **II.** Identification and critical assessment of the available evidence.
- **III.** Synthesis of the findings.
- **IV.** The drawing of relevant conclusions.

Systematic reviews aim to find as much as possible of the research relevant to the particular research questions and use explicit methods to identify what can reliably be said on the basis of these studies (Gough et al., 2012). Methods should not only be explicit but systematic with the aim of producing varied and reliable results.

As said before, systematic reviews are attempts to review and synthesise existing research in order to answer specific research / review question. Once a question is formulated, and its theoretical foundations established, the protocol is written. This protocol describes the steps that will be followed for the review. A protocol describes:

- **a)** The way existing studies are found.

b) How the relevant studies are judged in terms of their usefulness in answering the review question.

c) How the results of the separate studies are brought together to give an overall measure of effectiveness. Different questions and different theoretical bases will require different methodological approaches (gough et al., 2012).

We decided to slightly adapt Boland et al. (2014) nine step systematic review process. While Boland et al. (2014) proposes only one moment for applying the inclusion and exclusion criteria, after screening titles and abstracts and before selecting full-text papers, we argue that having two moments greatly reduces the necessary time for completing the review, especially when having a great number of initial citations.

The first moment, after Literature searching, quantitative data collected like peer review, published year, publication type, language will be filtered. That allows a considerable reduction of citations for title and abstract screening, the moment where the remaining inclusion and exclusion criteria will be applied. The following 9 steps will be followed.

1. Performing scoping searches, identifying the review question, and writing the protocol.
2. Literature searching.
3. Applying inclusion and exclusive criteria in quantitative data.
4. Screening titles and abstracts.
5. Selecting full text papers.
6. Quality assessment.
7. Data extraction.
8. Analysis and synthesis.
9. Writing up and editing.

Studies included in the review are screened for quality, so that the findings of a large studies can be combined. Peer review is a key part of the process; qualified independent researchers control the author's methods and results. For this research, we developed a protocol for the systematic review by following the guidelines and procedures of Boland, Cherry, and Dickson (2014), and consultation with e-learning specialists on the topic. This protocol specified the review question, search strategy, inclusion, exclusion and quality criteria, data extraction, and methods of synthesis.

Systematic reviewing can be a difficult and time-consuming activity (Boland et al., 2014). Nevertheless, with the amount, and complexity, of available information, there has been a real need to develop and establish a process to provide, in a concise way, the results of research findings.

Most notably, the dramatic increase in the amount of accessible research today makes it impossible for decision makers, policy makers and professionals to keep up to date with advances in their field. Systematic reviews allow concise synthesis of a large body of research and therefore address some of these issues.

The following sub-chapters describe in detail how the process went, necessary if any other researcher would want to replicate the study and part of the nature of conducting a systematic review. It's also a mean to inform of the needed steps to conduct a systematic review in Education, useful for someone who is planning to conduct one.

IV.1 PERFORMING SCOPING SEARCHES, IDENTIFYING THE REVIEW QUESTION AND WRITING THE PROTOCOL

Scoping searches aren't a comprehensive search, they "are performed to determine whether your topic area is suitable for a review" (Boland et al., 2014, p. 21) and to define the scope of the review by refining the review question.

Our first approach was to have a vision of a pedagogical model for STEAM education, without actually having a review question to start. Therefore, topic areas for initial scoping searches would be **STEM, STEAM, Strategies, Methodologies, Instructional design**.

We separated those topics in strings numbered from 1 to 4. Each string combined keywords using a OR Boolean operator to include possible alternatives in each topic area. A 5th and 6th string was added with the combination of the previous strings using a AND Boolean operator.

<u>*Keywords – Version 1*</u>

(1) ("STEM" OR "science, technology, engineering, and mathematics).
(2) ("STEAM" OR "science, technology, engineering, arts and mathematics").
(3) Strategies.

(4) Methodologies.
(5) 1 AND 2 AND 3 AND 4.

On the 17th of December 2021, we did our first query (string 5) at the **Web of Science** database. The query produced 1616 results, which, after filtering out books and e-books, our initial exclusion criteria, resulted in 714 identified citations.

We then browsed the results for its relevance, mostly by reading their titles and abstracts and we looked at their keywords field in order to find more suitable keywords to add to string (1) and (2) of our search strategy. The following keywords were added to the initial set, sorting them to their appropriate string.

Keywords – Version 2

(1) ("STEM" OR "science, technology, engineering and mathematics" OR "STEM education").
(2) ("STEAM" OR "science, technology, engineering, arts and mathematics" OR "STEAM education").
(3) Strategies.
(4) Methodologies.
(5) 1 AND 2 AND 3 AND 4.

We then restarted our query process with a set of new keywords (version 2). Query was performed on the 17th of December 2021. First, we did string (5) with a total of 851 results at the **Web of Science** database. We filtered those results by publication removing books and e-books, resulting in 37 records (search engine automatically removed duplicates). No keywords were found useful.

A third query was conducted (string 5), also on the 17th of December, this time at **ERIC** database, resulting in 2 citations. From those, 3 keywords were added to the existing search strategy: "Mathematics Education"," Science Education", "Interdisciplinary Approach".

Keywords – Version 3

(1) ("STEM" OR "science, technology, engineering and mathematics" OR "STEM education" OR "Mathematics Education" OR "Science Education").
(2) ("STEAM" OR "science, technology, engineering, arts and mathematics" OR "STEAM education" OR "Mathematics Education" OR "Science Education").
(3) (Strategies OR "Interdisciplinary Approach" OR Methodologies).

(4) 1 AND 2 AND 3.

The fourth query was conducted on the 21st of December 2021 at the ERIC database, leading to 135 citations. A further look at the descriptors related terms allowed for the keyword "Art Education" to be added to the first string and place together the first string with the second string.

Keywords – Version 4

(1) ("STEM" OR "science, technology, engineering and mathematics" OR "STEM education" OR "Mathematics Education" OR "Science Education" OR "STEAM" OR "science, technology, engineering, arts and mathematics" OR "STEAM education" OR "Mathematics Education" OR "Science Education" OR "Art Education").
(2) (Strategies OR "Interdisciplinary Approach" OR Methodologies).
(3) 1 AND 2.

The following query was performed at Web of Science database on the 21st of December 2021, conducting an advanced search for each string separately in titles (TI) as in topics (TS). We then combined the strings with the AND Boolean adding "golden ratio" and its synonyms. After a deeper look at the results we didn´t find suitable keywords to add to the search strategy.

Keywords – Version 5

(1) ("STEM" OR "science, technology, engineering and mathematics" OR "STEM education" OR "Mathematics Education" OR "Science Education" OR "STEAM" OR "science, technology, engineering, arts and mathematics" OR "STEAM education" OR "Mathematics Education" OR "Science Education" OR "Art Education").
(2) (Strategies OR "Interdisciplinary Approach" OR Methodologies).
(3) ("golden ratio" OR "golden section" OR "golden number" OR golden proportion" OR "divine proportion").
(4) 1 AND 2 AND 3.

Beside the already used databases (Web of Science and ERIC) we wanted to find other sources of relevant studies. In order to understand where to look, we used "Google Scholar". Search strategy had to be adjusted because of character limitations.

After searching, we faced a disproportionate number of results as compared with previous databases (About 1,720,000 results). This was due to the fact that most institutional databases used Dspace (repository application) configured to search all fields including full text, which produces a vast number of results. We therefore decided to not use the above-mentioned databases for scoping and for the rest of the review.

IV.2 ASSESSING THE SEARCH STRATEGY AND QUALITY OF RESULTS

At this moment it was decided to focus on understanding the volume and the quality of the results in order to "determine if the topic area was suitable for a review" (Boland et al., 2014, p. 21).

Using the latest keyword version, the combination of strings was analysed using the AND Boolean for a search performed on the 3rd of January 2022.

The combination of 1 AND 2 AND 3 produced 491 citations. After removing duplicates, 19 unique citations were found, which after title and abstract review, lead to relevant five citations:

Franco, J. E. M. (2018). *Art music in decline? Time for the Golden Ratio*. Máster en musicología. Escuela de Máster y Doctorado. Universidad de la Rioja.

The debate on the supposed crisis of art music is interpreted as an opportunity to propose new developments, focused on the combination of the traditional European aesthetic components (tonality, consonant intervals, harmonics) with new elements: the Golden Ratio (GR) and microtonality. The determinants of musical pleasure and their different combinations with GR are reviewed, focusing on the analysis of microtonal golden scales.

After reviewing and comparing several designs, it is concluded that a new auric construction of 34 equally tempered tones constitutes the theoretical model that best suits the objective of combining the components of music pleasure with the GR and microtonality.

Manea, T., & Williams, R. (2021). What's a Mathematics Teacher Doing in an English Classroom? In: E. Taylor & P. C. Taylor (eds.), *Transformative STEAM Education for Sustainable Development, Chapter 13*, pp. 234–251.

Born out of a perceived need rather than official necessity, the seeds of the idea that blossomed into our interdisciplinary curriculum approach emerged following a series of conversations between us when we travelled to Barcelona in 2009 to attend The Sixteenth International Conference on Learning.

Taking inspiration from one another – both experienced educators – we looked at ways that learning could be enhanced in our students by challenging the notion that our specialist subjects – English and Mathematics – should not live in isolation but could exist in a co-space, where each of us builds upon the work of the other.

Fenyvesi, K. et al. (2019). Mathematics and Art Connections Expressed in Artworks by South African Students. In: Wuppuluri, S., Wu, D. (eds) On Art and Science. *The Frontiers Collection*. Springer, Cham.

In this chapter, we examine a collection of drawings, and paintings from South African students between the ages of 10 to 17, that provide fresh and original perceptions to some already known topics, but also several unexpected connections between mathematics and art.

These works reference classic maths-art connections such as: golden ratio, spirals, infinity, and geometric figures; they also contain several personal reflections, unique discoveries and references to ethnomathematical connections within the African cultural heritage.

To introduce their pieces and themselves, students shared their own interpretations of their artworks. These commentaries make possible the identification of cognitive, emotional, and perceptual patterns. The chapter's aim is to provide insights into several pragmatic implications of the epistemological and ontological perspectives of mathematics and art connections in learning, and to introduce the MathArtWork method and terminology in the context of creative STEAM education.

Basogain, X. et al. (2020). STEM and STEAM in contemporary education: challenges, contemporary trends and transformation: a discussion paper. In: E. Smyrnova-Trybulska (ed.), Innovative Educational Technologies, Tools and Methods for E-learning, pp. 242–256.

This article, research review, focuses on STEM and STEAM in contemporary education as research literature review and viewed by experts from different countries: Austria, Poland, Russia, Spain and Ukraine. The article aims to provide opinions, views and reflections by an international team of experts from 6 universities from West, Central and East Europe on important topics: A. Robotics and STEM Education: Challenges, Contemporary Trends and Transformation; B. Microlearning – Effective Methods of E-Learning.

The paper includes the theoretical background of the topics discussed, research literature review, analysis of national and international experience, examples of practical achievements and a description of contemporary trends as well as reflections and conclusions.

Tenaglia, T. (2017). STEAM Curriculum: Arts Education As An Integral Integral Part Of Interdisciplinary Learning. *Graduate Education Student Scholarship. 11*.

This research project contains an extensive exploration of a STEAM (Science, Technology, Engineering, Art, and Math) approach to curriculum and instruction. STEAM is continually growing as an educational model in transition from the STEM educational (Science, Technology, Engineering, and Math) model.

The research is a response to a two-fold problem in education: a lack of preparation for future leaders in careers that require innovative-thinking and a need for advocacy for the arts in public education.

The literature review provides an expansive look at the present information available on STEAM frameworks, programs, curricula design, and teaching practices. Four emergent themes are illustrated within the research: problem solving practices, inquiry-based thinking, collaboration, and student choice. Currently there is not an official STEAM framework or a comprehensive STEAM curriculum plan for secondary educators.

The product that evolved from the STEAM research is a secondary education curriculum plan that includes a semester-at-a-glance, Know-Understand-Do (KUD) charts, learning maps, and unit plans. This interdisciplinary curriculum provides a solution to the research problem as it is intended to promote innovative solutions and the value of arts education.

In the discussion, the researcher explains how to utilise the curriculum components to foster interdisciplinary thinking and avoid superficial integrated or cross-curricular lesson plans by implementing the unit objectives.

Without actually analysing the full articles, as we were still in a preliminary phase, we assessed the usefulness of the results. Out of these 5 relevant results, we argue that 4 may contain the type of data we were looking for: a case study intended to influence the creation of the methodological framework and pedagogical strategy for STEAM.

At this moment, it was discussed what would be the best approach considering the insufficient citations obtained. One option was to look for more citations in other databases, another was to revise the keywords and strategy used, or eventually to continue the scoping and include more keywords using OR Boolean, or finally, to broaden the search.

Based on Boland et al. (2014) the choice should be to broaden the search, also, any other option might be a time-consuming risk. This decision would affect the project's initial expectations for a state-of-the-art review which assessed each country's partner context.

But in fact, based on the scoping search, there isn't enough data for that, but there is a fairly good chance of having enough data for a global or European context, based on the number of results of (1) AND (2).

IV.3 FIRST PROTOCOL

The previous scoping results and conclusions were revealed at a meeting with fellow project partners. Besides validating the broadening of the search and, therefore, taking full responsibility for this systematic review process, it was decided that we should understand the relation of “STEAM” and “Strategies” and “golden ratio” strings.

As so, our first review question, which was still open to refinement was: **What is the best framework and the STEAM-based pedagogical strategy to approach the golden ratio content?**

Inclusion criteria:

- Reviewed by experts, peer reviewed.
- Full article.

Exclusion criteria:

- Books, book parts and e-books.
- No original data.
- Not written in English.

From the latest keyword list (version 5), we then restarted the scoping search, starting from Web of Science database.

Keywords – Version 5

(1) ("STEM" OR "science, technology, engineering and mathematics" OR "STEM education" OR "Mathematics Education" OR "Science Education" OR "STEAM" OR "science, technology, engineering, arts and mathematics" OR "STEAM education" OR "Mathematics Education" OR "Science Education" OR "Art Education").

(2) (Strategies OR "Interdisciplinary Approach" OR Methodologies).

(3) ("golden ratio" OR "golden section" OR "golden number" OR golden proportion" OR "divine proportion").

(4) 1 AND 2 AND 3.

On the 18th of January 2022, a search at the same database as the previous query was performed. In a preliminary analysis of the title and abstracts, we found signs of valid results.

IV.4 PROTOCOL REFINEMENT

The review question was updated to include "STEAM teaching": **How to use the golden ratio as a common thread in STEAM teaching?**

Inclusion criteria:

- Reviewed by experts, peer-reviewed (to reduce bias).
- Addresses STEAM teaching.

- Full article.

Exclusion criteria:

- Books, book parts, e-books, and magazine articles.
- No original data.
- Doesn´t address STEAM teaching.
- Not written in English.

Another round of queries was conducted with satisfactory results. At this moment, it was believed that the scoping process had ended, and the literature search phase was started.

Data was collected at selected databases advised by a specialist, reaching the *Screening titles and abstracts* phase. In this step, two researchers, analysed the titles and abstracts of all citations collected and assigned one of three possible outcomes: *include, exclude* or *unsure*. The researchers were faced with a reduced number of *included* and *unsure* results and decided to understand the reasons.

First, a reduced number of titles and abstracts did in fact mention STEAM teaching explicitly, the majority does it implicitly. Second, there are no mentions of "golden ratio" competence.

After considering several options, it was decided to exclude the string related to STEAM teaching, use the data collected from this last procedure to improve the search strategy and restart the scoping process.

Proceeding with this new protocol to *literature search*, we ended up with 568 citations, after all including and excluding criteria was applied and removing duplicates. At this moment, it was believed that there were too many results and the possibility to do a peer review of so many titles and abstracts was inviable. It was decided to modify the search terms to reduce the number of results.

> "*If your search strategy retrieves too many records, you may want to refine your inclusion criteria and modify your search terms accordingly. You may wish to consider how you can limit your search results further, such as by year, language or publication type (for example, journal articles, books or letters).*"
> (Boland et al., 2014, p. 58).

IV.5 FINAL PROTOCOL

Review question: **How to use the golden ratio as a common thread in STEAM teaching?**

Inclusion criteria:

- Reviewed by experts, peer-reviewed (to reduce bias).
- Full article.

Exclusion criteria:

- Books, book parts, e-books, magazine articles and conference proceedings.
- No original data.
- Not written in English.

Keywords – Version 6

(1) (“STEM” OR “science, technology, engineering and mathematics” OR “STEM education” OR “Mathematics Education” OR ”Science Education” OR “STEAM” OR "science, technology, engineering, arts and mathematics" OR “STEAM education” OR “Mathematics Education” OR ”Science Education” OR "Art Education").

(2) (Strategies OR “Interdisciplinary Approach” OR Methodologies).

(3) (“golden ratio” OR “golden section” OR “golden number” OR golden proportion” OR “divine proportion”).

(4) 1 AND 2 AND 3.

IV.6 SELECTING DATABASES

After consulting a specialist, we were given a list of the most reputable databases in Educational Technology. We then cross-checked them with the current database subscription of the Universidade do Minho. The following databases matched:

- ERIC (http://eric.ed.gov/)
- Web of Science (https://www.webofscience.com/wos/woscc/basic-search) All journals included are peer-reviewed.
- Taylor & Francis Online (https://www.tandfonline.com)
- ACM Digital Library (http://dl.acm.org/) - When asked ACM support if all content was peer-review it was told that “ACM’s journals/transactions are

peer reviewed. Magazines are not.". We identified magazines, newsletters in the results as "Commun. ACM", "SIGCAS Comput. Soc.", "SIGCSE Bull.", "SIGGROUP Bull." and "eLearn" at the Journal field in Endnote and created a filter to exclude them in our final results, so it only included peer-review.

- ScienceDirect (https://www.sciencedirect.com) ScienceDirect is Elsevier's peer-reviewed full-text database.
- B-On portal https://www.b-on.pt/
- SCITEPRESS Digital Library https://www.scitepress.org/HomePage.aspx

IV.7 LITERATURE SEARCH

Our first try in literature search was based on Keywords version 6 from the scoping search.

Following an overview of the number of results collected on those databases are displayed and the outcome is discussed.

Overview of results collected

Total citations with unfiltered results was 1233, while peer-reviewed totalled 710 citations. Filter A, aggregating most of the inclusion and exclusion criteria produced 242 citations (see Table 2), which after removing duplicates, lead to 146 unique results.

Table 1. Number of citations found by database and filters for keywords version 6

Database	Results	Peer-Reviewed	Filter A
ERIC	367	96	46
Web of Science	28	28	13
Taylor & Francis Online	0	0	0
ACM Digital Library	40	18	9
ScienceDirect	5	5	4
B-On portal	365	135	63
SCITEPRESS Digital Library	287	287	56
Total (N)	**1233**	**710**	**191**

We then moved to the next step in the systematic review, screening titles and abstracts, but decided to go back to the scoping process and change the search strategy.

Our second try in literature search was based on Keywords version 6 from the scoping search.

Following an overview of the number of results collected on those databases are displayed and the outcome is discussed.

Overview of results collected

Total citations without any filtering was 3924, peer-review results 2396. Filter A, aggregating most of the inclusion and exclusion criteria produced 769 citations (see Table 3), which after removing duplicates ended in 568 unique results.

Table 2. Number of citations found by database and filters for keywords version 6

Database	Results	Peer-Reviewed	Filter A
ERIC	1051	406	180
Web of Science	228	228	84
Taylor & Francis Online	0	0	0
ACM Digital Library	111	76	43
ScienceDirect	44	44	23
B-On portal	2066	1219	339
SCITEPRESS Digital Library	281	281	52
Total (N)	**3924**	**2396**	**721**

IV.8 SCREENING TITLES AND ABSTRACTS

Two citations were removed from the review, as they were duplicates.

Two copies for assessment were made, one for each researcher involved in this process, so no prior knowledge of the assessment was known to any of the researcher to prevent bias decisions.

After reviewing the titles, 246 remained. Each researcher evaluated all 246 titles and assigned one of the 3 possible outcomes: Exclude, Include and Unsure. The remaining inclusive and exclusive criteria, the ones directly connected with the review question, were taken in consideration.

For the 246 titles and abstracts assessed, the number of observed agreements was 0,587 (58,7%). We also computed the Kappa coefficient of agreement, which corrects for chance agreement (Cohen, 1960). The Kappa coefficient for Stage 4 assessments was 0,15, which is characterised as “slight agreement” by Landis and Koch (1977). All disagreements were discussed and resolved by the two researchers, before proceeding to the next stage. As a result of this discussion, 40 citations were considered suitable for further review.

IV.9 SELECTING FULL-TEXT PAPERS

Out of the 40 citations, one was in Chinese and therefore excluded, 7 we couldn’t download the full text, as they weren't open access.

While on the quality assessment process, researcher 1 exported the list of the final 32 citations.

IV.10 QUALITY ASSESSMENT

For quality assessment, it was decided to adapt 2 versions of the Critical Appraisal Skills Programme (CASP), Dingsøyr and Dyba (2008) and (CASP) (2013) for the assessment of qualitative research. The tool used in this research can be found at Appendix 2.

The tool contained eleven criteria separated in two layers. The first contained three screening questions related to the quality of a study’s rationale, aims, and context. A “No” in any of these questions and the citation would be excluded, that was the minimum quality imposed in this systematic review. The second layer was related with the rigour, credibility and relevance and allowed the measurement of the citations value for the review.

The quality assessment was performed by 2 researchers for a total of 32 citations. The eleven criteria were graded in a “Yes”, “No” and “Can’t tell”. Conflicts were discussed and a final of 5 citations were selected for content analysis.

None of the citations were answered "Yes" to all questions, but six citations had only one "No". We used those criteria to select 6 citations. Below the references and the question answered as "No".

- Dana-Picard, T., Hershkovitz, S., Lavicza, Z., & Fenyvesi, K. (2021). Introducing the Golden Section in the Mathematics Class to Develop Critical Thinking from the STEAM perspective. Southeast Asian Journal of STEM Education, Vol. 2 No. 1, 151-169.
  - ✓ *Have ethical issues been taken in consideration? No.*
- El Bedewy, S., Kepler, J., Choi, K., Lavicza, Z., Kepler, J., & Fenyvesi, K. (2021). STEAM Practices to Explore Ancient Architectures Using Augmented Reality and 3D Printing with GeoGebra. Open Education Studies, 3(1), 176-187. Retrieved from DOI:10.1515/edu-2020-0150.
  - ✓ *Have ethical issues been taken into consideration? No.*
- Gardner, M. (1994). The cult of the golden ratio. Skeptical Inquirer 18, 243–247.
  - ✓ *Has the relationship between researcher and participants been considered adequately? No.*
- Green, C. (1995). All That Glitters: A Review of Psychological Research on the Aesthetics of the Golden Section. Perception 24(8):937-68. Retrieved from DOI:10.1068/p240937.
  - ✓ *Has the relationship between researcher and participants been considered adequately? No.*
  - ✓ *Have ethical issues been taken in consideration? No.*
- Markowsky, G. (1992). Misconceptions about the golden ratio. The College Mathematics Journal, 23(1), 2-19.
  - ✓ *Have ethical issues been taken in consideration? No.*

IV.11 DATA EXTRACTION

After the conclusion of the quality assessment, data extraction was started.

During quality assessment, there was some preliminary coding based on the study characteristics to assist the process, but also to help understand some trends and tendencies for future data extraction. As mentioned by Boland et al. (2014), this is one type of data needed for a systematic review, descriptive data, the other being analytical data.

For Descriptive Data it was extracted title, year, author(s), reference type and research methodology.

For Analytical Data, it was decided to gather goal/objective, scope, action, results, limitations/recommendations.

IV.12 ANALYSIS AND SYNTHESIS

This chapter in a Systematic Review is meant to present and summarize data (Boland et al., 2014).

For the analysis of qualitative data, we privileged a content analysis (Bardin, 1979). Bardin (1979) features content analysis as empirical and, therefore, cannot be developed based on an exact model. However, for its operation, we followed some basic rules.

First, the fundamental principles are explained: units of analysis, step models, working with categories, validity and reliability. Then, the central procedures of qualitative content analysis, inductive development of categories and deductive application of categories, are worked out.

Descriptive Data

Table 3. Summary of descriptive data

Short Citation	Full Citation	Ref. type	Methodology
Dana-Picard (2021)	Dana-Picard, T., Hershkovitz, S., Lavicza, Z., & Fenyvesi, K. (2021). Introducing Golden Section in the Mathematics Class to Develop Critical Thinking from the STEAM perspective. *Southeast Asian Journal of STEM Education*, Vol. 2 No. 1, 151-169.	Journal article	Qualitative descriptive research
El Bedewy (2021)	El Bedewy, S., Kepler, J., Choi, K., Lavicza, Z., Kepler, J., & Fenyvesi, K. (2021). STEAM Practices to Explore Ancient Architectures Using Augmented Reality and 3D Printing with GeoGebra. *Open Education Studies*, 3(1), 176-	Journal article	Qualitative descriptive research

	187. Retrieved from DOI:10.1515/edu-2020-0150		
Gardner (1994)	Gardner, M. (1994). The cult of the golden ratio. *Skeptical Inquirer* 18, 243–247.	Journal article	Qualitative descriptive research
Green (1995)	Green, C. (1995). All That Glitters: A Review of Psychological Research on the Aesthetics of the Golden Section. *Perception* 24(8):937-68. Retrieved from DOI:10.1068/p240937	Journal article	Qualitative descriptive research
Markowsky (1992)	Markowsky, G. (1992). Misconceptions about the golden ratio. *The College Mathematics Journal*, 23(1), 2-19.	Journal article	Qualitative descriptive research

Analytical Data

Analytical data was classified in eight categories: (i) modality, (ii) goal/objective, (iii) scope, (iv) action, (v) results, (vi) limitations/ recommendations.

Table 4. Summary of analytical data

Citation	Evidence
Dana-Picard (2021)	The Golden Section is a mathematical concept that is one of the most famous examples of connections between mathematics and the arts. Despite its widespread references in various areas of nature, art, architecture, literature, music, or aesthetics, discussions of the golden ratio often turn out to be false or misleading. Most of the incorrect statements are based on approximations or stem from the lack of checking the facts, making scientific mistakes in verifying the original scientific, historical, cultural context, or performing arbitrary operations in the measurements. This article offers geometric data and measurements, which allow the students to explore the golden ratio in various contexts through problem-solving activities. At the same time, we encourage students and their teachers to initiate critical discussions based on multidisciplinary research in the areas of STEAM about their findings. Such research-based critical discussion can help to discover the context of their results from several other perspectives in addition to mathematics.

	It can also reflect both the cultural and scientific validity of the otherwise mathematically correct - computations, as an essential expectation towards mathematics applied in a cultural or social context. For some of the topics described in this paper, we provide GeoGebra applets, which can let the reader explore the phenomena, and some pedagogical usage in classroom may yield examples for various populations of students. The topic is valuable in STEAM Education, with activities relying on European, Southeast Asian and Middle Eastern perspectives.
El Bedewy (2021)	In this study, we develop mathematical educational practices for students to explore ancient buildings using GeoGebra, Augmented Reality and 3D printing. It is an interdisciplinary approach, intertwining history, culture, mathematics, and engineering. For example, the 3D modelling of Cheomseongdae in Korea and the Temple of Dendera in Egypt can enable students to practice a multimodal set of traditional and innovative learning approaches. Students might use their mathematical knowledge to reflect on architectural and cultural history in a modeling task.
Gardner (1994)	Geometry has two great treasures: one is the Theorem of Pythagoras; the other, the division of a line into extreme and mean ratio. The first we may compare to a measure of gold, the second we may name a precious jewel. For more than a century, a cult with respect to the arithmetic ratio known as "divine proportion", "extreme and mean ratio", or "golden ratio", has flourished. This ratio is an irrational number, half the sum of 1 and the square root of 5 and is customarily represented by the Greek symbol for phi. This number can be characterised as the only positive number that becomes its own reciprocal by subtracting 1. It is surprising the presence of this number in several mathematical domains, for instance, the golden ratio is related to a generalised Fibonacci sequence, to a logarithmic spiral generated by whirling squares and golden rectangles, to the pentagram of the ancient Pythagorean Brotherhood, and to many other delightful constructions in which is unexpectedly. Since the Renaissance, an enormous interest has emerged in applying the golden ratio in architecture, painting, sculpture, nature, and even to poetry and music. The golden rectangle's cult as the most aesthetically pleasing of all rectangles and the efforts to find it in the most varied contexts, as well as the presence of the golden ratio in the proportions of the Great Pyramid of Egypt or in those of the Greek Parthenon, or its use by Leonardo da Vinci in his work, are some examples. However, these examples and their veracity are not consensual and have been questioned. In this paper, Martin Gardner,

	based on George Markowsky's work, discusses misconceptions about some of these beliefs, refuting some ideas for lack of proof, or evidence, and for relying on the choice of measures that best fit the desired result. In most of the examples given by the golden ratio enthusiasts, and presented in this paper, the measures are not precise, and in some cases are associated with them, not the golden ratio but numbers approximated by it. The modelling or mathematization of real situations stimulate interdisciplinary learning and opportunities for the development of STEAM education contexts. In most cases, mathematical modelling of real contexts is performed by approximate mathematical models or with some degree of inaccuracy. In real situations, presented as examples or that contextualise mathematical problems, it is pertinent that teachers and students are aware of the possibility of inaccuracies that result from the contrast between the rigour of mathematics and the uncertainty of reality. This text warns the reader about the application of the golden ratio in various situations, highlighting examples in which its application is irrefutable and others, very frequent in educational contexts, which are questionable.
Green (1995)	Since at least the time of the Ancient Greeks, scholars have argued about whether the golden section—a number approximately equal to 0.618—holds the key to the secret of beauty. Empirical investigations of the aesthetic properties of the golden section date back to the very origins of scientific psychology itself, the first studies being conducted by Fechner in the 1860s. In this paper historical and contemporary issues are reviewed with regard to the alleged aesthetic properties of the golden section. In the introductory section the most important mathematical occurrences of the golden section are described. As well, brief reference is made to research on natural occurrences of the golden section, and to ancient and medieval knowledge and application of the golden section, primarily in art and architecture. Two major sections then discuss and critically examine empirical studies of the putative aesthetic properties of the golden section dating from the mid-19th century up to the 1950s, and the empirical work of the last three decades, respectively. It is concluded that there seems to be, in fact, real psychological effects associated with the golden section, but that they are relatively sensitive to careless methodological practices.
Markowsky (1992)	The golden ratio, also called by different authors the golden section [Cox], golden number [Fi4], golden mean [Lin], divine proportion [Hun], and division in extreme and mean ratios [Smil, has captured the popular imagination and

	is discussed in many books and articles. Generally, its mathematical properties are correct. stated, but much of what is presented about it in art, architecture, literature, and aesthetics is false or seriously misleading. Unfortunately, these statements about the golden ratio have achieved the status of common knowledge and are widely repeated. Even current high school geometry textbooks such as [Ser] make many incorrect statements about the golden ratio. It would take a large book to document all the misinformation about the golden ratio, much of which is simply the repetition of the same errors by different authors. This paper discusses some of the most commonly repeated misconceptions.

Table 5. Summary of Goal / Objective category

Citation	Evidence
Dana-Picard (2021)	STEAM education is included in the article with a special emphasis on Technology, Art and Mathematics connections, that is, technology-supported mathematical activities around artistic works. In the research, it was aimed to motivate students, to embody how to use the golden ratio in school learning, and to create research opportunities that can be used in the field of STEAM by giving place to mathematical analysis of real-life situations in which the golden ratio is used, based on previous studies on the golden ratio and the experiences of the authors. Besides, being able to initiate critical discussions about cultural issues in the mathematics course was also among the goals.
El Bedewy (2021)	The researcher's goal is to introduce new mathematical concepts to students and explore them in various dimensions using physical representations such as 3D printing and digital representations such as AR. These representations are intended to enable visualisation of various forms and spaces. The program goal is to implement mathematical modelling of ancient architectures to foster the student's mathematical and engineering knowledge while connecting to the culture and history.
Gardner (1994)	Evidence of the presence of the golden ratio in several domains of Mathematics, in particular, in Algebra and Geometry, and discuss misconceptions about its application in architecture, painting, sculpture, nature, among others.

Green (1995)	The golden section has been the focus of great interest for a long time. the purpose of this article is to review the results with particular interest in psychological experiments to verify the beauty of the golden ratio.
Markowsky (1992)	The article addresses the mathematical properties of the golden ratio. The author states that much of what is presented about the golden ratio in art, architecture, literature, and aesthetics must be more accurate. Unfortunately, these misleading claims about the golden ratio have reached the status of common knowledge and are widely repeated, even in geometry textbooks. The article's goal is to discuss some of the most commonly repeated misconceptions in the literature about the golden ratio.

Table 6. Summary of Scope category

Citation	Evidence
Dana-Picard (2021)	Within the scope of the research, the compatibility of the ratios in some architectural and artistic works with the golden ratio was examined, together with the mathematical and geometry-based calculations of the golden ratio. In the same context, the relationship of examples that can be included in STEAM education with mathematics and art is discussed in detail.
El Bedewy (2021)	Researchers carried out educational activities to connect various technological knowledge to real-world examples while using mathematics knowledge in the process of selecting ancient buildings and designing them on a computer. The researchers introduced the activities of designing Cheomseongdae in South Korea and Temple of Dendera in Egypt in 3D space and reflecting them through AR or actualizing them through 3D printing.
Gardner (1994)	This article aims to characterise the golden ratio, highlight its transversality in Mathematics and discuss its application in examples from the arts, architecture, nature, among others, demystifying some ideas that have been propagated for many years.
Green (1995)	In the first part of the article some mathematical occurrences of the golden section are examined. The second part refers to the empirical research between the nineteenth and sixties on the aesthetic properties of the golden section. In a third section the most recent discoveries and theoretical explanations of psychologists are examined, focusing in particular on concerted efforts to show the effects of the golden section. The research brings light to the claims made involving human preference for the golden ratio in aesthetics and discusses the reasons for such statements.

Markowsky (1992)	This article is a reflection on the golden ratio and its applications, based on works developed by several authors who questioned the exalted cult of the golden ratio.

Table 7. Summary of Action category

Citation	Evidence
Dana-Picard (2021)	In order to ensure that the golden ratio is handled with critical discussion in the research, some classroom practices are included, showing that the golden ratio is seen in architectural works and the calculations are analyzed with the help of geogebra program. In addition, a framework was presented on how to apply the golden ratio and the areas where the golden ratio is interactive in the classroom.
El Bedewy (2021)	Based on the information from the historical documentations, modelling procedures were constructed using GeoGebra to guide the students in a step-by-step way to develop a 3-D representation model of the two ancient buildings: Cheomseongdae in South Korea and Temple of Dendera in Egypt. This program was conducted in collaboration with a Korean and an Egyptian mathematics education researcher. GeoGebra was chosen because it can help students in understanding the mathematical representations in various forms as in algebraic equations or as 2D/3D views.
Gardner (1994)	This article is a reflection on the golden ratio and its applications, based on works developed by several authors who questioned the exalted cult of the golden ratio.
Green (1995)	The golden section was subjected to numerous tests trying to analyse every psychological and methodological factor that could have influenced esthetical preferences. Several surveys and numerous experiments were carried out with people who were asked to choose the rectangle they liked best.
Markowsky (1992)	The golden ratio arises from dividing a line segment so that the ratio of the whole segment to the larger piece is equal to the ratio of the larger piece to the smaller piece. This was called division in extreme and mean ratio by Euclid. The golden ratio appears in many geometric constructions. Throughout this paper, the author presents passages from several studies that affirm the presence of the golden ratio in some works of art or architecture. According

	to the article's author, in some cases, the authors drew golden rectangles that conveniently ignore parts of the object under consideration. Without any clear criteria or standard methodology, it is not surprising that they can detect the golden ratio. According to the article's author, it is unfortunate that many writers on mathematical subjects treat measurements of real objects as if they were exact numbers. To discuss intelligence claims, creating some guidelines for dealing with sizes and proportions is necessary. Therefore, he decides to use ratios with a maximum of 3 significant figures, as we have a margin of error of around ‡2%. The paper focuses on eight cases in which the golden ratio was miscalculated.

Table 8. Summary of Results category

Citation	Evidence
Dana-Picard (2021)	As a result of the research, it was concluded that the use of the activity examples shared in the research in the classroom environment would be beneficial for students to make critical discoveries, debunk mathematical myths and understand approximate calculations in mathematics. It has also been shared that these positive effects will directly increase the motivation of mathematics. In addition, in the results of the research, it was stated that the use of shared activities in the research can be used as a powerful approach in education, interdisciplinary learning, which is frequently emphasised in STEAM education. It has also been emphasised that handling cultural structures together with other disciplines in STEAM education together with dynamic software such as GeoGebra can help students get to know their own culture.
El Bedewy (2021)	Students were able to recognize that the oldest science that has been with humanity is mathematics through the process of redesigning historical artefacts in GeoGebra. Reproducing these ancient architectural models with AR and 3D printing is an achievable combination and provides an interdisciplinary education in history, culture, mathematics, and engineering.

	From the educational point of view this may foster creativity while they are modelling such complex temples and it may help in collaboration between students if they are considering group work.
Gardner (1994)	In educational environments, examples illustrating the application of the golden ratio in various contexts are often presented. In this way, interdisciplinary learning is stimulated and opportunities for the development of STEAM education contexts emerge. However, many of the examples usually considered are not mathematically proved. This article points out some of these examples and elucidates the reader for the relevance of their discussion.
Green (1995)	Many experimental results seem to uncover the existence of an universal criterion of beauty based on golden ratio; some of them suggest that the preference is innate while others reduce it to educational and cultural factors.
Markowsky (1992)	Many assume that the names "golden ratio" and "golden section" are ancient. For example, François Lasserre states, "The proportion, famous throughout antiquity, has been known since Leonardo da Vinci's time as the golden section." [Las, p.76]. However, the adjective "golden" in connection with Φ is relatively modern. Even the term "divine proportion" goes back only to the Renaissance. David Eugene Smith states: "The solution (of the problem of drawing 36° and 72° angles) is related to the division of a line in extreme and mean ratio. This was referred to by Proclus when he said that Eudous (c. 370 .c.) 'greatly added to the number of the theorems which Plato originated regarding the section.' This is the first trace of this name for such a cutting of the line. In comparatively modern times, the section appears first as 'divine proportion', and then, in the 19th century, as the 'golden section.'

Table 9. Summary of Limitations / Recommendations category

Citation	Evidence
Dana-Picard (2021)	In the research, it has been suggested to perform mathematical analysis of cultural architectural works with dynamic software programs in order to increase students' mathematical motivation and critical discussion skills. In

	this context, it was emphasised that the lesson plans and practices prepared on the basis of STEAM education should be increased.
El Bedewy (2021)	The educational program proposed doesn't apply to any particular country; it can be implemented in various countries to various cultures because it is a conceptual program and the concepts it holds can be applied to any ancient architecture in any place around the world. GeoGebra was chosen for the modelling process over other types of software, such as sketch-up or CAD as they are used to perform very sophisticated modelling, but it is not easy for students to apply mathematical objects or use geometric knowledge.
Gardner (1994)	The modelling or mathematization of real situations is, in most cases, performed by approximate mathematical models or with some degree of inaccuracy. In real situations, presented as examples or that contextualise mathematical problems, it is pertinent that teachers and students are aware of the possibility of inaccuracies that result from the contrast between the rigour of mathematics and the uncertainty of reality.
Green (1995)	In conclusion, after more than a century of studies the final result of research is that the golden section has no particular aesthetic qualities.
Markowsky (1992)	The author concludes that a point overlooked by many Golden Ratio enthusiasts is the fact that measurements of real objects can only be approximations. The surfaces of real objects are not perfectly flat. Furthermore, it is necessary to specify the accuracy of any measurements and realise that inaccuracies in measurements lead to greater inaccuracies in proportions.

V. ANALYTICAL DATA

Performing a systematic review is clearly very laborious and requires a great deal of persistence. Even more so when it's part of a European funded project, like this one, with deadlines and expectations which are not only based on this review author's personal context and planning but must be coordinated with the partners involved. Still, it is a highly valuable experience.

Since the time of the great thinkers of ancient Greece, the meaning of "art" still has no consensual solutions. The first perhaps belongs to the Hegelian dialectical philosophy of the 18th century, where art is defined as "a resource of subjective development of the spirit starting from the real and the inner representation", as well as the Kantian transcendental philosophy, for whom "the interpretative search for the universal character justified the possibility of scientific knowledge that is based on experience", are imposed on the a priori forms of sensitivity and understanding, characteristic of the cognitive psychological functions of human individuality.

Later, the Austrian philosopher Ludwig Wittgenstein (1889-1951), influenced by the behaviourist current on behaviour, explains how language manages to represent the world stating that the "pictorial theory of meaning, the proposition is the figurative representation of facts". This procedure is still currently used in scientific research on art, serving as essential reference material for those who seek art as content.

Between classical and contemporary authors, critiques are woven that unfold in the creation of concepts and definitions that do not complement each other, thus creating successive interrogations. In this theoretical perspective between semiotics, perception and creativity of the work of art, it would be feasible to consider this narrative with clarity in relation to the interpretations enunciated by the authors.

In this way, creativity is inserted in art as the act of imagining, creating, going beyond evidence, generating energy, potential for original ideas and communicative actions. In the essence of a higher level than the mechanical process and in consciousness itself, creativity transforms reality, in interaction with the environment, be it educational, socio-political, historical, or cultural.

According to Almeida (2000), he states that behind a work of art there is an author who used intuition, knowledge and creativity to produce it, and even if he is no longer with us, and a long time has passed, there is a history of the artist performer.

However, the aesthetic emotion is registered in the work of art, in addition to the theme, composition and material technique, in this case not caused by us, but the mark as a fingerprint, as well as the gesture of the artist himself, because time is inexorable to our reality. Despite the successive definitions of art, and clashes of thought between authors, these continue to be inefficient about what art can be. In these dichotomies between definitions, the word creativity always appears, which becomes a common denominator between authors, and the artist as a being who develops his own ideas about art, practicing them as an act of creating objects, as well as fruition and intuition directed towards creativity.

Researcher David de Prado states in the article "Feature Interview": *(...) creativity is neither taught nor learned through books, nor by listening passively. It is learned through daily practice, reflecting on the multiple forms of expression, language and through transforming imagination* (Prado & Paolantonio, 2000, p. 97). It also mentions that creativity is not about a passive recipe, but about developing and mastering the creative imagination.

Within the scope of creativity, the author simplifies his way of expressive knowledge and raises arguments to be thought and practiced. Man as a creative being and inventor of things, using imagination that transforms into creativity in science and poetics. David de Prado argues that methodological concepts about creativity, do not allow reaching deep levels of free expression and spontaneity at the level of ideas.

> *"The creative process in art: a lived journey and an amazing creative synthesis Free creative process, in which we have nothing to gain and nothing to lose. The gush of intuition consists of a rapid and continuous flow of options, options, and options. When we improvise with our heart, following this flow, the options are transformed into images, and the images into new options, with such a quickness of time to feel fear or regret before what the intuition is telling us".*
>
> (Nachmanovitch, 1993, p. 47).

In addition to all these definitions of creativity, the one which today is claimed to be the most consensual is provided by Todd Lubart, professor of Psychology at the Université Paris Cecartes and endorsed by a number of authors: "*Creativity is the ability to produce a production that is both new and adapted to the context in which it manifests itself*" (Lubart, 2003). Many authors consider that creativity only applies in the arts and sciences, but despite some specificity, the approach to creativity can be generalised to all areas.

The interpretation of creation from the point of view of Fayga Ostrower (2012, p. 28), questions that creating does not "represent a relaxation or a personal emptying" and that for creation to happen, the inner feeling becomes necessary so that we can build a creative force.

Regarding the intuition factor, Ostrower points out that this is at the base of the creation processes, it is the first is the foundation for the creative process, thus opening other fields for possible and passible means. In constant transformation, the creative process is built through sensitivity, through the experience of emotions and sensations, and these are reflected in the product of creation. Creativity generates thoughts and proposals of motivations which evolve potentialities, activates the creative process, energizes the capacity for invention and develops the critical sense.

The creative faculty is a characteristic peculiar to the human gender, enabling the human species to project itself into the future, providing mankind with the advancement from the condition of mere biological species to that of human gender.

In the educational context, creativity points not only to the creative motivation of the student but also of the educator, who must equally assume a creative posture. Rogers (1954) states that creativity would be in the human tendency to self-realization, to realize its potentialities.

This author also states that the 'psychologically' safe place has to be created, that is, there has to be an environment conducive to creativity. In a classroom, the risk of having ideas has to be taken, ideas considered valid, and mistakes seen as another learning opportunity. In the classroom, it is important to use creative teaching strategies and processes, creating a non-threatening atmosphere.

Carl Rogers (1954) also stresses the importance of a climate of psychological safety, the acceptance of a valued individual, empathic understanding of the learner and the acceptance of their internal evaluation. However, educational systems increasingly tend to privilege the development of abstract knowledge to the detriment of other human qualities such as imagination and creativity.

Carl Rogers (1985) also comments on the failure of schools with regard to creativity, stating that they overemphasise conformism, passivity and stereotyping to the detriment of certain conditions such as intuition, openness to feelings and emotions, aesthetic interests and curiosity. Creativity has to be valued and encouraged, as people only learn what they feel is stimulating.

According to Robert Sternberg (2003), professor of psychology at Yale University, schools continue to neglect the creative abilities of their children. It transmits a ready-made knowledge and leaves little room for creativity, invention, fantasy, or initiative of the student. It is adaptation and submission that are reinforced even though it is theoretically recognised that the promotion of creativity is fundamental in today's society. For this author, the educational system that does not give space to creativity.

Through art education, it is possible to stimulate the child's intelligence, sensitivity, and activity. The teacher should not condition the student, but motivate him to free expression, expression of feelings, creativity, and spontaneity. Art education will contribute to the construction of the self in its fullness, providing the relationship between the child and the world around her, so that she becomes an integrated, autonomous, critical, and creative individual.

Artistic education should be properly valued in our society, to provide an integral development of the child through the artistic disciplines (visual arts, music, dance and theatre), which should have the same weight as the other disciplines in the cognitive, sensory and emotional development. In all societies, school is one of the most important foundations, assuming the duty and responsibility of preparing man for the problems he will encounter.

Creativity is a key element in social transformation; it is a question which comprises each person's individual identity and also the identity of everyone in the world. One of the hallmarks of 20th century pedagogy was the enhancement of creativity, this became the rule, and the concept of art as expression became strong, leading art education to the thought of "free doing". Expression was part of the creative spirit, which could not be cut, invaded, hampered or contaminated.

Contextualising the creative process in art education, it can be said that it is necessary to create an environment for this development to take place. The children have an active role and, with the help of the teacher, can learn significantly to develop her creativity. For this to happen, in the act of creation, the child must have total freedom, without any kind of imposition or rule.

Cooperation, respect, and freedom are the key words for creating an atmosphere conducive to the creative development of the child. The teacher presents a role of mediator and guide throughout the process. I believe that this is the methodology that provides greater independence to the child and stimulates more significant learning.

Artistic education allows independence, organization, and insertion of students into society. For this to happen, it is necessary to always bear in mind that education should always be directed towards its global character, and teaching should promote interdisciplinarity and transdisciplinarity.

In the context of interdisciplinarity at school, it is important that all members involved in the teaching and learning process begin to visualise the whole, realising that the most interesting and creative results occur based on dialogue between the various areas of knowledge.

For an education aimed at interdisciplinarity, it is necessary to review the contents, methodologies, and activities and what the project is intended to provide students, namely: self-expression (free, critical, creative, conscious); responsibility (initiative, participation, collaboration); curiosity and autonomy in the construction of knowledge, among others (Andrade, 2010). The mission of each teacher will be accomplished if she feels, that has done everything that was considered necessary and possible in the performance of her function, not forgetting, however, that as a teacher, is also susceptible to improvement. For this to be possible it is fundamental that each teacher engages in a prior process of self-knowledge and becomes aware that today, and increasingly, teaching must be seen as a process of mutual learning (Jesus, 2003).

V.1 GOLDEN RATIO AS A SCHOOL SPACE

Study of the contemporary scientific literature reveals that school space is the fundamental field in which both the interaction between teachers and students, and the deployment of pedagogical practices are realized. Hence, the role played by school space is extremely important since it may influence either directly or indirectly the quality of the interpersonal relationships.

The formation and suitability of the school space, with the essential material conditions which ensure the existence of a pleasant and creative learning environment are the goals for meeting the needs and demands of daily school activities.

Recent scientific research has revealed that the structure and organization of school classrooms in many countries have remained unchanged for years. It is noted that the classrooms at all levels of education (pre-school, primary, secondary, tertiary) seem to have remained unchanged, stagnant and mono-functional for many decades, despite the developments in contemporary pedagogical approaches. Was verified in the contemporary school classrooms that the organization of the space in school classrooms is based on the reproduction of the traditional features of older school buildings.

A characteristic example of this is the arrangement of the desks, which cannot be easily altered, and as a result, even today they are arranged in parallel rows and columns facing the board and the teacher's desk. In a space like this, lessons tend to be carried out that focus mainly on the teacher, which reveals the implementation of strict hierarchical rules of framing as he is the main focal point in the room.

Recent scientific data lead to the conclusion that school space is mainly "mono-functional", in other words, it functions in one direction, which is from the teacher towards the students and not the other way around, which leads to stereotypical and inflexible pedagogical practices.

The quality of the educational process, the role of the "teacher/orator" and the "student/executor of instructions", limited students to act autonomously and intervene in the educational process, to develop their critical skills and creativity. In the sequence of this topic, a number of scientific studies that investigate the relationship between students choosing where to sit in the classroom and their learning outcomes, have shown that students who choose to sit at the back of the classroom wish to be out of the teacher's line of sight and do not wish to participate in the learning procedure, the opposite happens with the students who are sitting in front, they participated more.

School space, as a learning environment, can create the conditions so that the educational process may become more effective and pleasant. The findings from a lot of the research agree on the discovery that school space is an especially significant factor in the implementation of everyday educational activities and the shaping of the relationships that develop within the school environment. This is because a good quality school environment makes a significant contribution to the improvement in the quality of the educational work provided.

Image 9. Photo by Max Fischer from Pexels

Recent studies recognize the importance of the teacher's ability to develop a creative relationship with the space, to use it as a pedagogical tool and to make use of it in the framework of his teaching. In this case, the teacher needs to have the ability to transform, rearrange and decorate the space, creating a learning environment that can encourage the creative movement of the pupils in the space to achieve positive learning outcomes.

School space needs to adapt to new pedagogical methods, which favour the implementation of "invisible" learner-centered pedagogical practices, in order to facilitate a new means of acquiring school knowledge (Bernstein, 1996, 2000). An alternative spatial arrangement of the school classroom is pointless if not accompanied by corresponding changes in the pedagogical practices implemented by the teachers. Consequently, the role of the teacher in the pedagogical upgrading of the classroom and the use of space as a pedagogical tool, is decisive.

Concerning this research, we can think about the classroom space with a harmonious table layout according to the golden ratio. It is possible by this way to promote the deconstruction of the common hierarchic class design, the critical thinking, the teamwork, the competencies, and the creativity. In this sense, the disposal of classroom furniture according to the golden ratio can acts as a tool or common denominator for STEAM pedagogy.

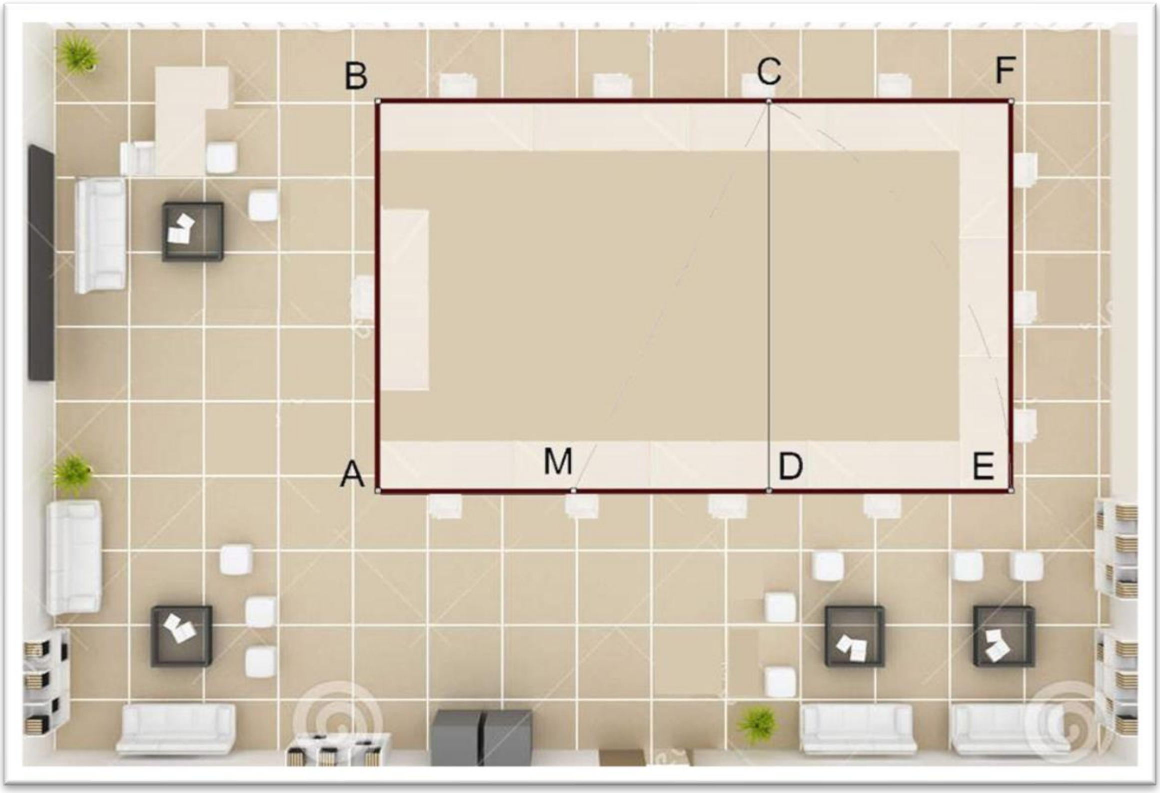


Figure 1. Virtual image of a classroom with a golden ratio layout.

Bibliographical review of scientific papers concerning the pedagogical redesign of the school space considering criteria regarding the organization and psycho-social aspects.

VI. DEVELOPING LESSON PLANS WITH THE STEAM APPROACH

In the 21st century, it is one of the most basic goals for learners to be productive individuals who can solve problems using their creativity. To achieve this goal, an effective and functional curriculum is needed, as expected. Many applications and plans have been made and continue to be made on the STEAM education approach that emerged in this context.

One of the most important steps of this Erasmus+ project, which we aim to be a guide for teachers, is the design of the sample teaching plan to be applied. Since this study is an exemplary practice and a guideline, this study is based on the development of short continuous implementation plans, not a whole year of education.

Many lesson plans prepared in accordance with the STEAM education approach have taken their place in the literature. However, upon careful examination, the plans are quite different from each other in some contexts. The main reason for this is that these plans are based on different STEAM approaches. Of course, it should not be forgotten that research sheds light on applications and continuous development continues in this process.

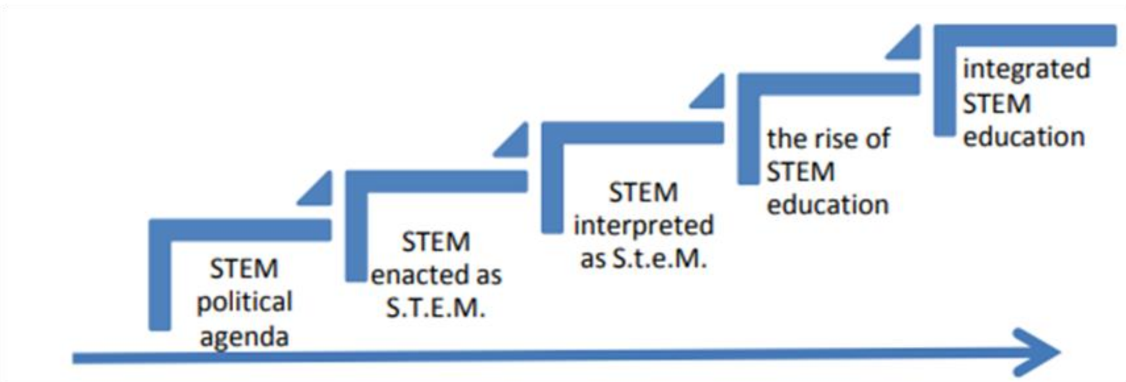


Figure 2. A STEM timeline - integrated STEM education (Blackley & Howell, 2015)

When the literature is examined, as can be seen in Figure 1 for this new educational approach, the name STEM was used first. Although the idea of teaching separate disciplines together was first started, the concept of STEAM began to be used after art took its place in this approach as a discipline.

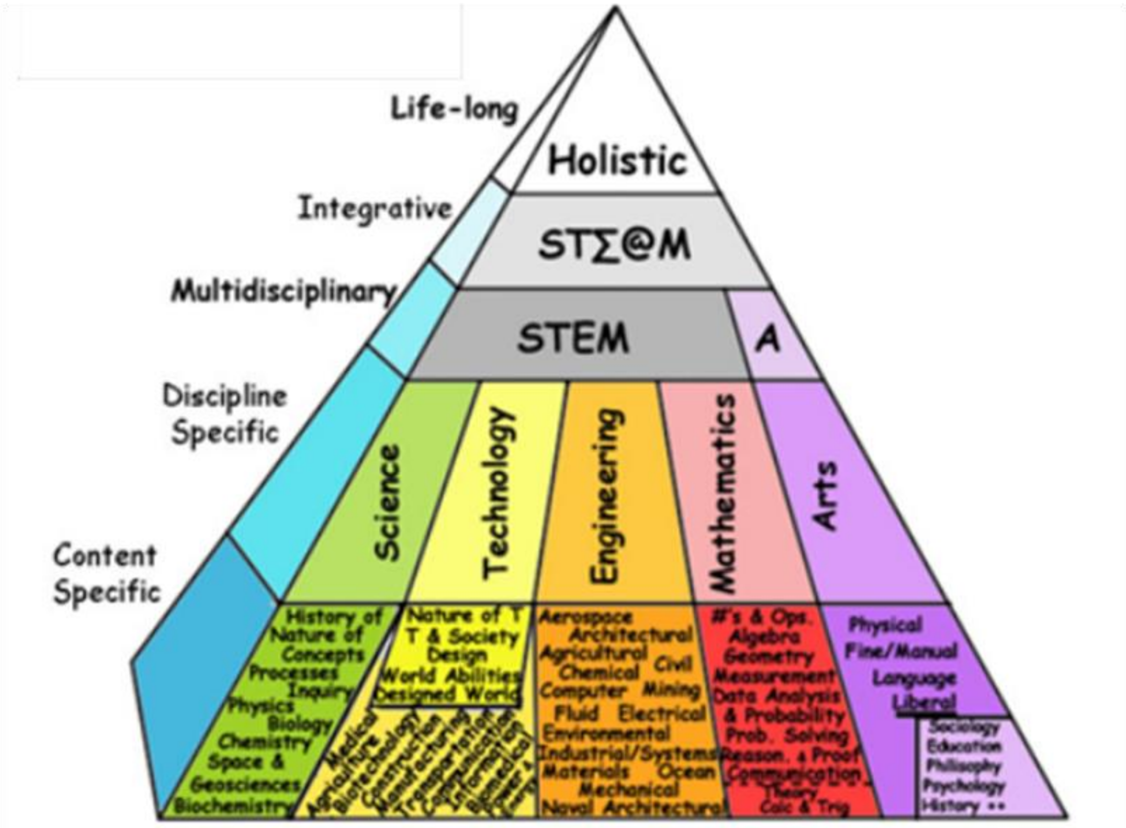


Figure 3. STEAM Pyramid (Yakman, 2008)

While the name of this new educational approach has evolved from STEM to STEAM, of course, the only difference has not been the name change. While being described with the name STEM, an interdisciplinary educational approach was taken as the basis. However, with the inclusion of art in the approach, the idea of an integrated program began to emerge.

With the taking place of art in this approach, "communication, coloration, critical thinking, creativity" twenty-first century skills, which are defined as 4C, have started to be seen as a desired output in the targeted student behaviours.

In this context, in the STEAM approach, students should be supported to be inquisitive individuals, opportunities should be created for students in terms of project production, and we should train students who can use technology effectively and design throughout this process (Bender, 2018).

Teaching programs, which are teachers' guides, are the most important helpers in achieving this goal, which is not so easy to achieve. In addition, it is very important to be meticulous in achieving the above-mentioned goals in these programs and that the curriculum is based on real-life problems.

As it is known, the STEAM approach adopts the principles based on the constructivist learning theory. For this reason, while preparing the lesson plan in accordance with the STEAM approach, constructivist learning cycles are widely used in accordance with the theoretical basis. These learning cycles still continue to develop with research and applications. The model, which was initially called the triple model, began to be replaced by the 5E and then the 7E model over time. Models are called by these names because of all of the steps that will guide the practitioners in the cycles start with the letter E.

Table 10. Various Learning Cycle Models (Keleş, 2010)

3E Model	5E Model	7E Model
		Elicit
	Engage	Engage
Exploration	Explore	Explore
Explanation	Explain	Explain
Expansion	Elaborate	Elaborate
	Evaluate	Evaluate
		Extend

The learning cycles, each step of which are given in Table 1, are very flexible models in terms of subject and area to which they can be applied. Since it can be used in many disciplines, it is thought that it will be functional and efficient for a lesson plan to be prepared in accordance with the STEAM approach. For this reason, it was deemed appropriate to use the 7E model for all lesson plans prepared within the scope of this project.

In the "elicit" step, which is the first step in the 7E learning cycle model, by asking questions about the subject, students' readiness is tried to be determined and students are prepared for the lesson. In the second step, the "engage" step, students are asked to think deeply about a problem and produce a solution and test in their minds whether the solutions will work or not. In the third step, "explore", the concepts related to the subject are tried to be explained with group work. In this step, teacher guidance is very important.

Whether the concepts are understood correctly and clearly can be tested by the teacher. In the fourth step, "explain", it is requested to apply the concepts learned in the previous step. Thus, it is tried to produce a solution to the problem asked at the beginning of the process by using the concepts.

Again, at this stage, the teacher should guide the students. The new information and concepts learned in the fifth step, "elaborate", are compared with the information obtained at the beginning of the process. Thus, it is ensured that the students make sense of the information they have acquired. In the "evaluate" step, which is the sixth step, many process and result-oriented evaluations can be made, and students may be asked to evaluate their ideas and what they have learned.

At this step, group studies, concept maps and research-examination studies can be done. Finally, in the seventh step, "extend", the teacher may be asked to evaluate the new information gained by the students and check the problem solutions students have applied.

An example template for a lesson plan that can be prepared by the 7E learning cycle model is shared in Appendix-3.

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APPENDIXES

APPENDIX 1 – TITLE AND ABSTRACT REVIEW TOOL

			Researcher 1 (R1)	Researcher 2 (R2)	R1 | R2	Excluded on:
ID	Title	Abstract				
1	Title	Abstract	Include Exclude Unsure	Include Exclude Unsure	Include Exclude	Reason
2	Title	Abstract	Include Exclude Unsure	Include Exclude Unsure	Include Exclude	Reason

APPENDIX 2 – QUALITY ASSESSMENT TOOL

Screening Questions	Researchers		
	R1	R2	Final
<u>1. Is there original data?</u> Consider: –Is the paper based on research (or is it merely a "lessons l earned" report based on expert opinion? –Does the study present empirical data?	Yes No Can't tell	Yes No Can't tell	Yes No
<u>2. Is there a clear statement of the aims of the research?</u> Consider: - What was the goal of the research? - Why it was thought important? - Its relevance. - Does it address course design in e-learning courses and does it relate with dropout and/or attrition?	Yes No Can't tell	Yes No Can't tell	Yes No

3. Is there an adequate description of the context in which the research was carried out? Consider whether the researcher has identified: - The type of course, based in either formal or non-formal education. - The nature of the institution that promotes the course. - The team involved developing the course (e.g. skills, tasks).	Yes No Can't tell	Yes No Can't tell	Yes No
If question 1, 2 and 3, receive a "No" response do not continue with the quality assessment.			
Detailed Questions	**Researchers**		
	R1	**R2**	**Final**
4. Was the research design appropriate to address the aims of the research? Consider: – Has the researcher justified the research design (e.g. have they discussed how they decided which methods to use)?	Yes No Can't tell	Yes No Can't tell	Yes No
5. Was the recruitment strategy appropriate to the aims of the research? Consider: –Has the researcher explained how the participants or cases were identified and selected? –Are the cases defined and described precisely? –Were the cases representative of a defined population? –Have the researchers explained why the participants or cases they selected were the most appropriate to provide access to the type of knowledge sought by the study? - If there are any discussions around recruitment (e.g.	Yes No Can't tell	Yes No Can't tell	Yes No

why some people chose not to take part) –Was the sample size sufficiently large?			
<u>6. Was the data collected in a way that addressed the research issue?</u> Consider: –Were all measures clearly defined (e.g. unit and counting rules)? - If the setting for data collection was justified. - If it is clear how data were collected (e.g. focus group, semi-structured interview etc.). - If the researcher has justified the methods chosen. - If the researcher has made the methods explicit (e.g. for interview method, is there an indication of how interviews were conducted, or did they use a topic guide)? - If methods were modified during the study. If so, has the researcher explained how and why? - If the form of data is clear (e.g. tape recordings, video material, notes etc). - If the researcher has discussed saturation of data. –Whether quality control methods were used to ensure completeness and accuracy of data collection.	Yes No Can't tell	Yes No Can't tell	Yes No
<u>7. Has the relationship between researcher and participants been considered adequately?</u> Consider: - If the researcher critically examined their own role, potential bias and influence during (a) Formulation of the research questions (b) Data collection, including sample recruitment and choice of location. - How the researcher responded to events during the study and whether they considered the implications of any changes in the research design.	Yes No Can't tell	Yes No Can't tell	Yes No

8. Have ethical issues been taken in consideration? Consider: - If there are sufficient details of how the research was explained to participants for the reader to assess whether ethical standards were maintained. - If the researcher has discussed issues raised by the study (e.g. issues around informed consent or confidentiality or how they have handled the effects of the study on the participants during and after the study). - If approval has been sought from the ethics committee.	Yes No Can't tell	Yes No Can't tell	Yes No
9. Was the data analysis sufficiently rigorous? Consider: - If there is an in-depth description of the analysis process. - If thematic analysis is used. If so, is it clear how the categories/themes were derived from the data? - Whether the researcher explains how the data presented were selected from the original sample to demonstrate the analysis process. - If sufficient data are presented to support the findings. - To what extent contradictory data are taken into account. - Whether the researcher critically examined their own role, potential bias and influence during analysis and selection of data for presentation.	Yes No Can't tell	Yes No Can't tell	Yes No
10. Is there a clear statement of findings? Consider: –Are the findings explicit (e.g. magnitude of effect)? –Has an adequate discussion of the evidence, both for and against the researcher's arguments, been demonstrated? –Has the researcher discussed the credibility of their	Yes No Can't tell	Yes No Can't tell	Yes No

findings (e.g. triangulation, respondent validation, more than one analyst)? –Are limitations of the study discussed explicitly? –Are the findings discussed in relation to the original research questions? –Are the conclusions justified by the results?			
<u>11. How valuable is the research?</u> Consider: - If the researcher discusses the contribution the study makes to existing knowledge or understanding e.g. do they consider the findings in relation to current practice or policy?, or relevant research-based literature? - If they identify new areas where research is necessary. - If the researchers have discussed whether or how the findings can be transferred to other populations or considered other ways the research may be used.	Yes No Can't tell	Yes No Can't tell	Yes No

APPENDIX 3- LESSON PLAN TEMPLATE

Theme:
Subtopic:
Grade Level:
Time:
Developer/s:

Learning Objectives:

Elicit	Materials	Method / Technique
Engage	**Materials**	**Method / Technique**
Explore	**Materials**	**Method / Technique**
Explain	**Materials**	**Method / Technique**
Elaborate	**Materials**	**Method / Technique**
Evaluate	**Materials**	**Method / Technique**
Extend	**Materials**	**Method / Technique**